MALARIA EARLY WARNING SYSTEM IN THE SOLOMON ISLANDS USING SEASONAL CLIMATE OUTLOOKS

SUMMARY

Title
Malaria early warning system in the Solomon Islands using seasonal climate outlooks

Service
– Use of relationship between El Niño/Southern Oscillation (ENSO) index and malaria incidence to build a prototype early warning system for public health authorities
– Satellite-derived sea-surface temperature data (a critical component of the ENSO index)

End users
Ministry of health, local public health organizations

Intermediate users
Solomon Islands Meteorological Service

Application(s)
– Seasonal climate outlooks and predictions
– Prediction of malaria incidence
– Warnings and advisories to public health authorities

Models used
N/A

Climate data records used
– Precipitation, temperature (maximum, minimum), relative humidity 1975–2007 (in situ records on Solomon Islands)
– AVHRR-derived SST 1982–present (used in calculating SST anomalies for the ENSO index)
– ICOADS SST

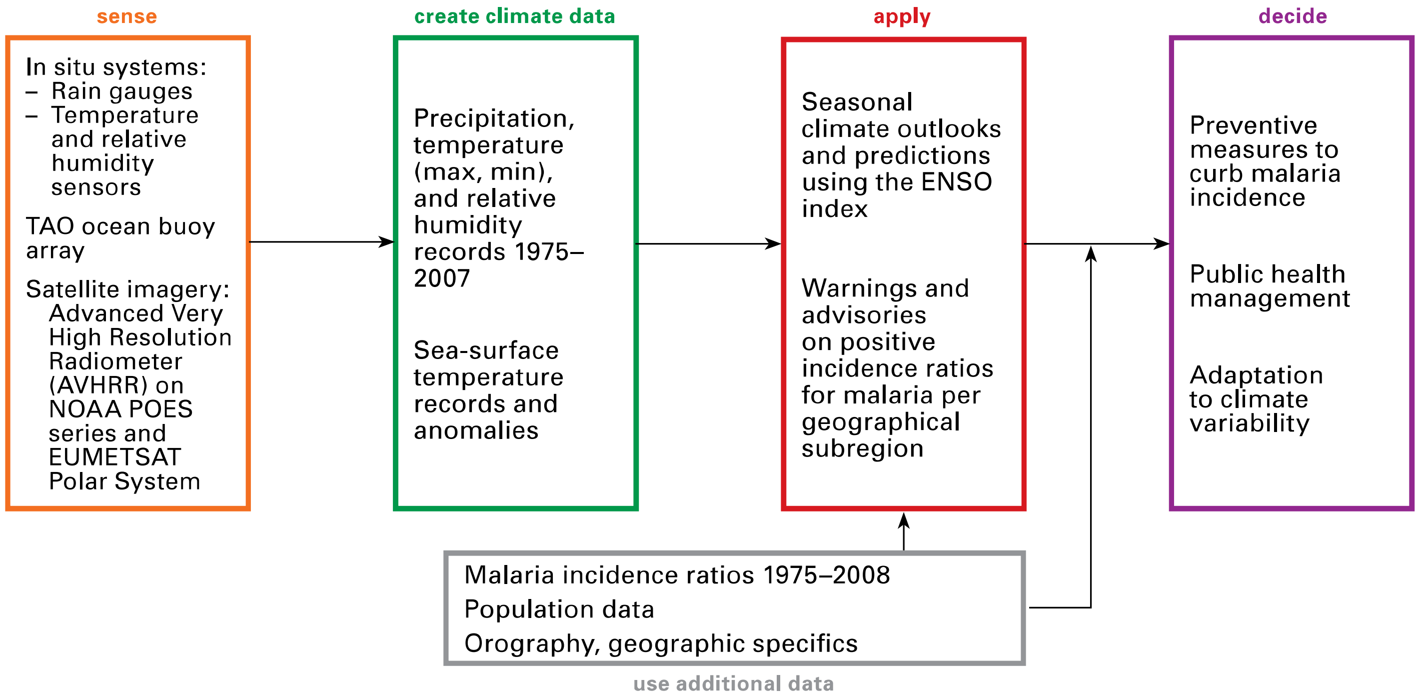
Satellite observations used
AVHRR instrument flown on NOAA POES series and EUMETSAT Polar System

Agencies that produce records
– Solomon Islands Meteorological Service (for in situ CDRs)
– NOAA, EUMETSAT (for AVHRR)

Sustainability of service (demonstration or ongoing)
Pilot project, with prospect for transition into an operational information and warning service

Close-up of a mosquito

INFORMATION FLOW



DESCRIPTION

Climate variability and malaria incidence

Malaria is a leading cause of death in the Solomon Islands (WMO, 2011). The age-adjusted death rate of approximately 30 per 100 000 of population ranks the tropical western Pacific islands as 33rd in the world. Malaria continues to have high economic and social costs including low productivity at work and absenteeism in schools. The impact of climate change on the health sector is also significant (WMO/WHO, 2012).

Mosquitoes can carry Plasmodium falciparum, a life-threatening form of malaria parasite, which accounts for 60–70% of all confirmed cases in the Solomon Islands. Epidemics tend to occur when environmental conditions such as rainfall, temperature and relative humidity create optimal conditions for mosquito breeding.

The climate of the Solomon Islands is significantly influenced by the El Niño/Southern Oscillation (ENSO) phenomenon. El Niño conditions are generally associated with below-average rainfall and above-average temperatures, while La Niña conditions are generally associated with above-average rainfall and below-average temperatures. The tendency for the ENSO phenomenon to develop and then persist makes it possible to forecast seasonal rainfall and other hydroclimatic variables with some accuracy, employing key climate indices such as the Southern Oscillation Index and patterns of sea-surface temperature anomalies.

The Niño3.4 central equatorial sea-surface temperature anomaly index is an important and commonly accepted indicator of central tropical Pacific El Niño conditions (Reynolds and Smith, 1994; IOC, 2015). The index is used for detecting and predicting the ENSO phenomenon (Figure 1). It is calculated using satellite-derived sea-surface temperatures (mainly from AVHRR data), and in situ observations from the Tropical Atmospheric Ocean project moored buoy array. The sea-surface temperature anomaly is calculated relative to climatological seasonal cycle-based data collected between 1982 and 2005 and using the International Comprehensive Ocean-Atmosphere Dataset (ICOADS; Woodruff et al., 2011). Climate satellite records with higher precision (for example, (A)ATSR) but less geographical and temporal coverage are used to correct biases in the AVHRR record (GHRSST, 2015).

In combining local climate records of temperature and rainfall, malaria incidence data and a standard ENSO sea-surface temperature anomaly, there is potential to forecast elevated risk periods of malaria outbreaks in the Solomon Islands with a sufficient lead time to reduce the potential incidence of the disease through targeted control strategies.

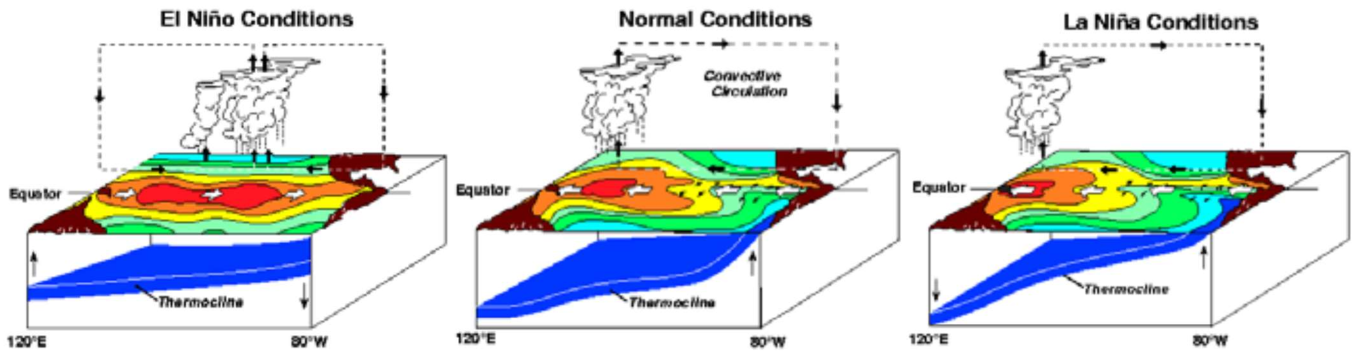


Figure 1. Ocean-temperature (surface and subsurface) and rainfall patterns over the Pacific during El Niño, La Niña and normal conditions (NOAA, 2015). The ENSO phenomenon has a significant impact on weather conditions in the Pacific Ocean and beyond, changing the likelihood of heavy rainfall and droughts in many parts of the world.

A prototype malaria early warning system

The application of seasonal forecasts to the development of a prototype malaria early warning system in the Solomon Islands has been the objective of a project funded by the Australian government. The project was defined and carried out in close collaboration with key users of the system, the Solomon Islands Meteorological Service and the Solomon Islands Medical Training and Research Institute, so that climate information could be effectively integrated into decisionmaking. The project formed part of a larger pilot programme funded by Australia to support Pacific islands' management of and responses to climate variability and change in vulnerable sectors, such as health.

A principal objective of the project was to develop malaria outlooks based on the historical relationship between malaria incidence and the effects of the ENSO phenomenon on rainfall and temperature. The influence of temperature on malaria development appears to be non-linear (IPCC, 2014) and vector-specific (Alonso et al., 2011). Analyses in East Africa show that abundance, distribution and disease transmission are affected in different ways by precipitation and temperature (Kelly-Hope et al., 2009). Determining the precise nature of those relationships in the Solomon Islands was therefore a key component of the project and the subject of lengthy investigation.

Once the relationships were well understood, it became possible to develop a prototype early warning system: the National Meteorological Service could issue bulletins signalling periods in which future climate conditions were likely to favour high malaria incidence; medical services and residents could then take measures to minimise infection. It is also expected that such forecasts would provide sufficient lead time for healthcare services to efficiently incorporate into their planning the need for additional medical resources during these periods.

Lessons from data

In collaboration with the Solomon Islands Medical Training and Research Institute, records of both confirmed and suspected malaria cases for nine provinces were obtained for the period 1975–2007. Corresponding climate data for this period, including rainfall, maximum and minimum temperature and relative humidity data, were prepared by the Solomon Islands Meteorological Service. Records were collected for each of the country's nine provinces and were collated into five regions for the purpose of this study.

Region-specific grouping of data gave significant consideration to geographical location, orographic effects and the availability of malaria outpatients and climate data. Considerable adjustments were made to population data and associated malaria incidence records to take account of the data grouping. Malarial incidence was calculated as a Positive Incidence Ratio, which is defined as the number of positive cases per 1 000 persons.

The numbers of confirmed malaria cases were identified using data from the period 1975–2008 during the peak infection period (December to May). Linear and non-linear regression techniques were used to relate Positive Incidence Ratio to climate factors (such as temperature and rainfall) and non-climate factors (such as population growth). The analyses (Figure 2) show that the incidence of malaria peaks during the wet season (December to April). Somewhat counter-intuitively, however, it was also evident that above-median rainfall during the wet season tends to suppress the number of malaria cases: mosquito breeding sites are likely flushed out by the above-average rainfall in such cases. Below-median rainfall during the wet season tends to increase the incidence of malaria.

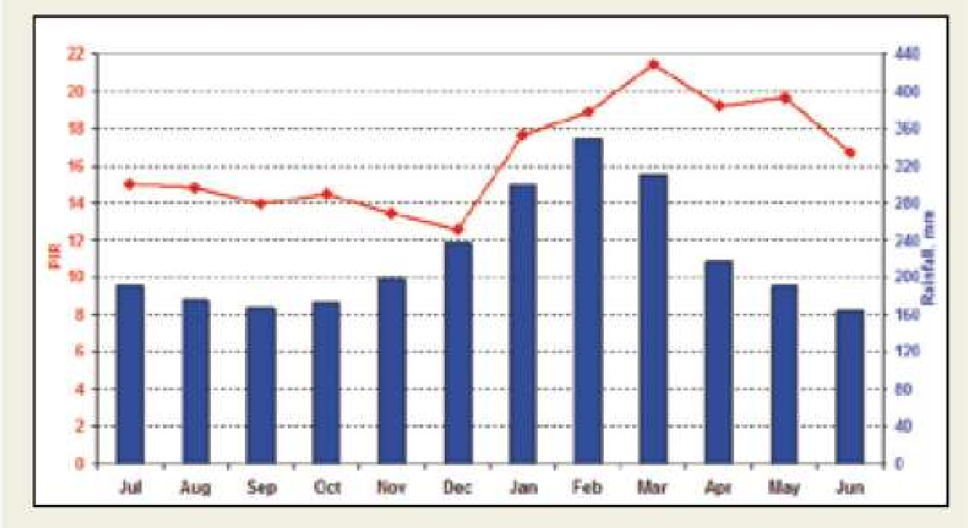


Figure 2. Relationship between Positive Incidence Ratio for malaria on the Solomon Islands and rainfall during the year

Sources: Australian Bureau of Meteorology and WMO, 2012

Those results indicate that malaria tends to be more prevalent during El Niño events and less so during La Niña events. The maximum correlation between rainfall and Positive Incidence Ratio is subject to a significant lag time: the Ratio lags behind rainfall by approximately two months. This makes rainfall a useful parameter for forecasting Positive Incidence Ratio with sufficient lead time to inform planning and management decisions. On the other hand, the influence of temperature on numbers of malaria cases tends to have a shorter lag time. This means that lower than normal rainfall from November to January, followed by higher than normal temperatures in December and January would trigger a high incidence of malaria.

In summary, climate factors (rainfall and temperature) explained up to 70% of variability in the number of malaria cases. An early warning system for malaria based on seasonal climate forecasts for the peak infection period was therefore assessed to be viable for the Solomon Islands.

Towards an operational service

This project has been a pioneering case study of the impact of climate variability and possible climate change on the health of a Pacific community. A prime example of the use of climate information to facilitate improvements in malaria management is the Malaria Early Warning System in sub-Saharan Africa, developed over the last decade by the Roll Back Malaria partners under the auspices of WMO. Now that a robust relationship between ENSO phenomena and malaria incidence in the Solomon Islands has been established, the development of a similar system for the Solomon Islands is considered feasible.

The results of the research described here were presented in a workshop in the capital of the Solomon Islands, Honiara, and received wide coverage in the local media. Following the workshop, Dr Jennifer Mitini, Director of National Health Research and Training, said:

> "The research has answered one of the burning questions we have really tried to answer in the past, but we didn't get results as comprehensive as this [study]. The most important next step is for [the health community] to start working with the Meteorological Services to use the information they collect to help guide us in our control actions, planning and management of malaria cases."

An operational early warning system will require the establishment of a number of protocols and procedures for ensuring the rapid and timely exchange of information between the national meteorological service and relevant health providers, as well as an effective means of informing key government entities and the wider population. The end results will be improved healthcare outcomes for residents of the Solomon Islands and a more appropriate provision of health services during periods of high malaria incidence. Those results will improve the standard of care, the quality of healthcare outcomes, and lead to cost savings due to a more efficient use of resources. In turn, those improvements will likely lead to benefits in the overall well-being of the local population, particularly during periods of high malaria risk and infection potential. There will also be long-term benefits to work and education output (due to a reduction in lost productivity from illness and incapacity), as well as

Figure 3. Climate information helps provide an early warning system for malaria outbreaks in the Solomon Islands, allowing for improved healthcare and a reduction in lost productivity. (WMO, 2012)

improvements to quality of life, subjective life satisfaction and possibly average life expectancy (Figure 3).

Sustained support by satellite operators to an operational health warning system relying on the detection of ENSO is now in place, because of the consistent availability of satellite sensors (such as AVHRR and SLSTR) that enable the derivation of sea-surface temperatures and the calculation of an ENSO index.

Although the study has focused on the Solomon Islands, the methodology could be more widely applied in a number of other Pacific island nations to improve the management of malaria in Papua New Guinea and Vanuatu, dengue fever in Fiji and waterborne pathogens in Kiribati. Contrary to common belief, this study has concluded that if a certain rainfall threshold is exceeded, the incidence of malaria can reduce significantly.

It is not clear whether direct extrapolation of the results of this study to other areas is appropriate, due to factors which can significantly affect the epidemiology of climate-related illness. Those include the substantial differences in the effects of the ENSO cycle on different Pacific island countries and variations in topography and geography across the region.

(Note: The material of this case study is strongly based on text and images published in *Climate ExChange* (WMO, 2012), pp. 100–103.)

References

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