CHANGING THE LANDSCAPE OF DENGUE FEVER

DENGUE FEVER IS NOW THE FASTEST SPREADING MOSQUITO-BORNE DISEASE IN THE WORLD. **GINA TSAROUCHI** TAKES A LOOK AT A NEW SYSTEM THAT COMBINES EARTH OBSERVATION TECHNIQUES WITH HYDRO-METEOROLOGICAL DATA TO FORECAST OUTBREAKS

Standing water provides the perfect breeding grounds for mosquitos in Hanoi, Vietnam

The prevalence of dengue fever poses a global health issue, with the World Health Organization (WHO) estimating that half the world's population is now at risk from the mosquito-borne viral infection. The WHO says it has seen an eightfold increase in reported cases over the past two decades, from 505,430 cases in 2000 to more than 2.4 million in 2010 and 4.2 million in 2019.

The key to controlling dengue is costly surveillance and control of the mosquitos that spread the disease. Forecasting outbreaks can contribute greatly to the distribution of scarce resources and better forecasting equals better management and – the hope is – fewer cases in the long term. Predicting outbreaks also enables more targeted support to help communities reduce mosquitos using simple measures such as improving water storage and waste management and personal protection such as mosquito coils.

Developed by a consortium led by HR Wallingford, the Dengue Model forecasting Satellite-based System (D-MOSS) forecasts outbreaks six months in advance and is the first functional system that uses Earth observation (EO) data, in-situ observations and seasonal climate forecasts to issue forecasts on a regular basis. A prototype D-MOSS system is operating in Vietnam and, owing to the success of the trial there, it is now being implemented in Malaysia and Sri Lanka, with rollouts planned in four other Asian countries.

Based on the latest epidemiological research, hydro-meteorology and informatics, D-MOSS is designed to overcome the practical challenges of forecasting mosquito-borne diseases. For instance, it takes into account how temperature influences mosquitos' development, reproduction rates, mosquito distribution, how rainfall creates or destroys breeding sites, land-use, and mosquito-control measures.

By collecting 20-year histories of satellite-based EO data from services including NASA DAAC, Copernicus and NOAA CFSv2, D-MOSS can establish the relationship between these factors and dengue. Gaps in the satellite data are filled using interpolation and comparison to in-situ observations from ground stations, which creates a 'big data' repository of hydro-meteorological, land cover and population variables. These include maximum and minimum temperature, precipitation, soil moisture, urban and peri-urban area percentages, and population totals. The system uses an information architecture based around the spatio-temporal structure of each dataset, calculating data for every Vietnamese province by harmonising the datasets into a timeseries set of polygons taken from the province boundaries, referred to as a MultiPolygonSeries.

At the start of the forecasting process, a water availability model is used to generate a set of parameters representing the amount of water present at the Earth's surface, such as total run-off and evapotranspiration. After this, the relationships between the hydro-meteorological variables and the numbers of cases of dengue fever are created by a statistical superensemble generated by Bayesian model averaging. This process is repeated monthly or weekly as new data arrives from satellites and as new cases of dengue fever are reported.

To produce forecasts, D-MOSS incorporates the UK Met Office's GloSea5 six-month seasonal forecast of hydro-meteorological variables to predict outbreaks. Forecasts are displayed on a private website using interactive maps, charts and tables, and, to make the results relevant to policymakers and practitioners, they are presented as the probability that cases will exceed thresholds set by organisations such as the WHO.

Innovations

Harnessing the power of geospatial innovation was instrumental in creating an accurate forecasting system that can be rolled out around the world.

To ensure D-MOSS's usefulness and long-term usability, a complete and accurate picture needs to be built and kept up to date. Key to this is access to high-quality satellite EO data from sensors such as MODIS that have up to 1km resolution, are available for free, allow for automated collection, cover the whole of Vietnam and have a revisit daily. Further data product developments will only make D-MOSS even more accurate over the coming years.

The system also depends on much improved seasonal meteorological forecasts and benefits from their continual enhancements. Analysis over a long period of time has revealed consistent biases in different places and at different times of the year. To account for this, D-MOSS incorporates a bias-correction algorithm, which refers to historical hindcast data from the GloSea5

New EO products are changing the face of dengue fever management

model. El Niño also has a proven effect on outbreaks of dengue fever around the world and, for Vietnam, the D-MOSS team statistically confirmed this link and included the El Niño index in the set of variables. There may be other factors at play, too – the team is currently investigating possible links between dengue fever and the Indian Ocean Dipole phenomenon, for example.

D-MOSS's component-based architecture means it can be implemented from local to national scales around the world, and can also be easily extended to incorporate new EO data when additional satellites are launched as well as new links with other social and environmental factors.

On-the-ground success

Whilst the technical accomplishments of this project are many, the most important achievement is that D-MOSS works for its users. Authorities in Vietnam are beginning to use the forecasts to make important decisions and testimony from local health officials is coming in thick and fast – some have even linked using the system with a lowered death rate.

For instance, Dr Pham Ngoc Thanh, deputy director of the epidemiology department at Tay Nguyen Institute of Hygiene and Epidemiology, says D-MOSS is helping to bridge the gap between early warning and early action, as well as to reduce the number of dengue cases and mortality rate.

The potential of D-MOSS is huge. In its current form it could help more than three billion people, but it could easily be extended to zika and even to malaria. Perhaps it's not surprising, therefore, that the United Nations Development Programme has hailed it as a flagship project.

In the short term, D-MOSS is helping to reduce the ever-increasing death toll from dengue. However, EO is in its infancy, computing capabilities are on a sharp upwards curve, and D-MOSS can adapt to and hone new data. It's not inconceivable, therefore, that the landscape of vector-borne disease prevention could look very different in the not-too-distant future.

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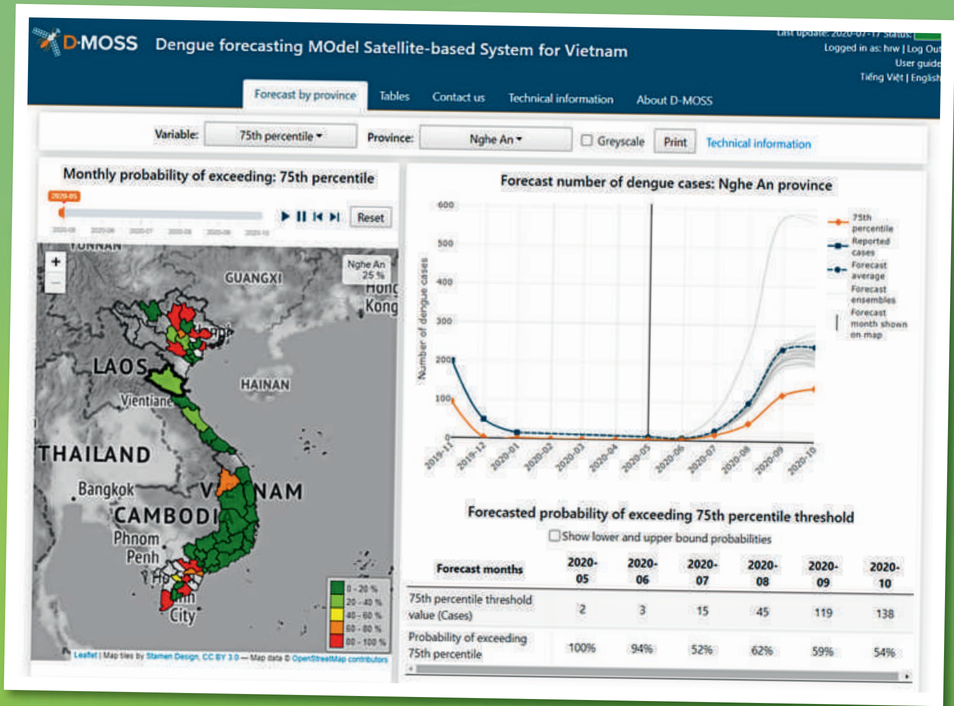

The D-MOSS interface forecasts dengue up to six months in advance (shown using test data)

Around half the world's population is at risk from mosquito-borne dengue fever