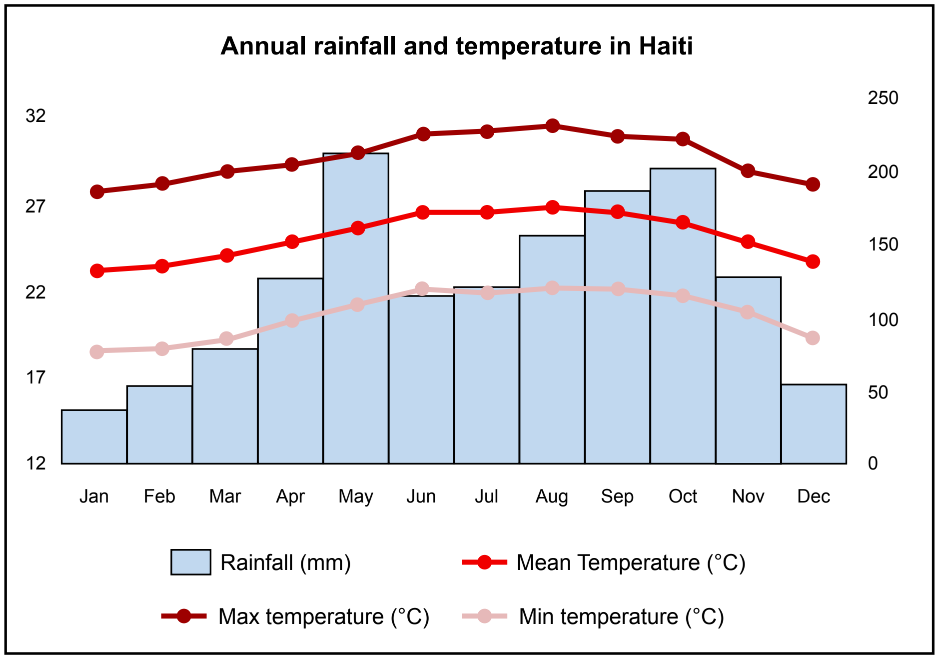
BRIEFING

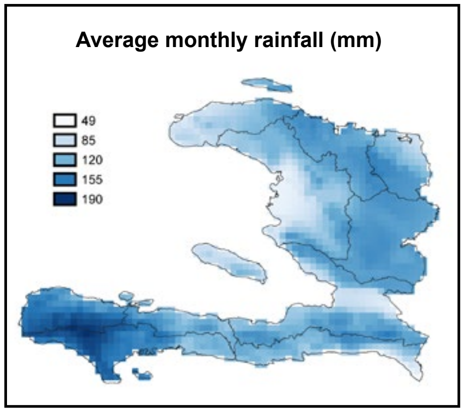
CLIMATE OF HAITI

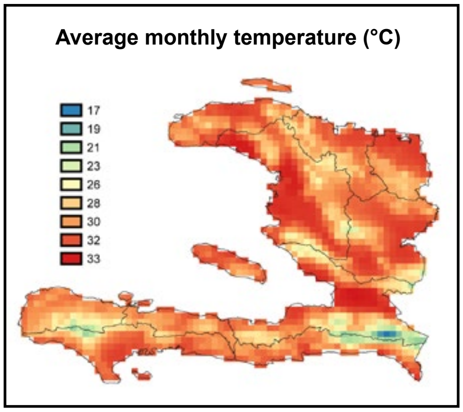
Haiti has a hot and humid tropical climate. Daily temperatures typically range between 19°C and 28°C in the boreal winter and 23°C to 33°C during the summer.

Due to Haiti's rugged landscape, complex shoreline, and surrounding warm waters, the rainfall across the country is highly heterogeneous. Annual precipitation in the mountainous areas averages 1,200 mm, while the annual precipitation in the lowlands is as low as 550 mm.

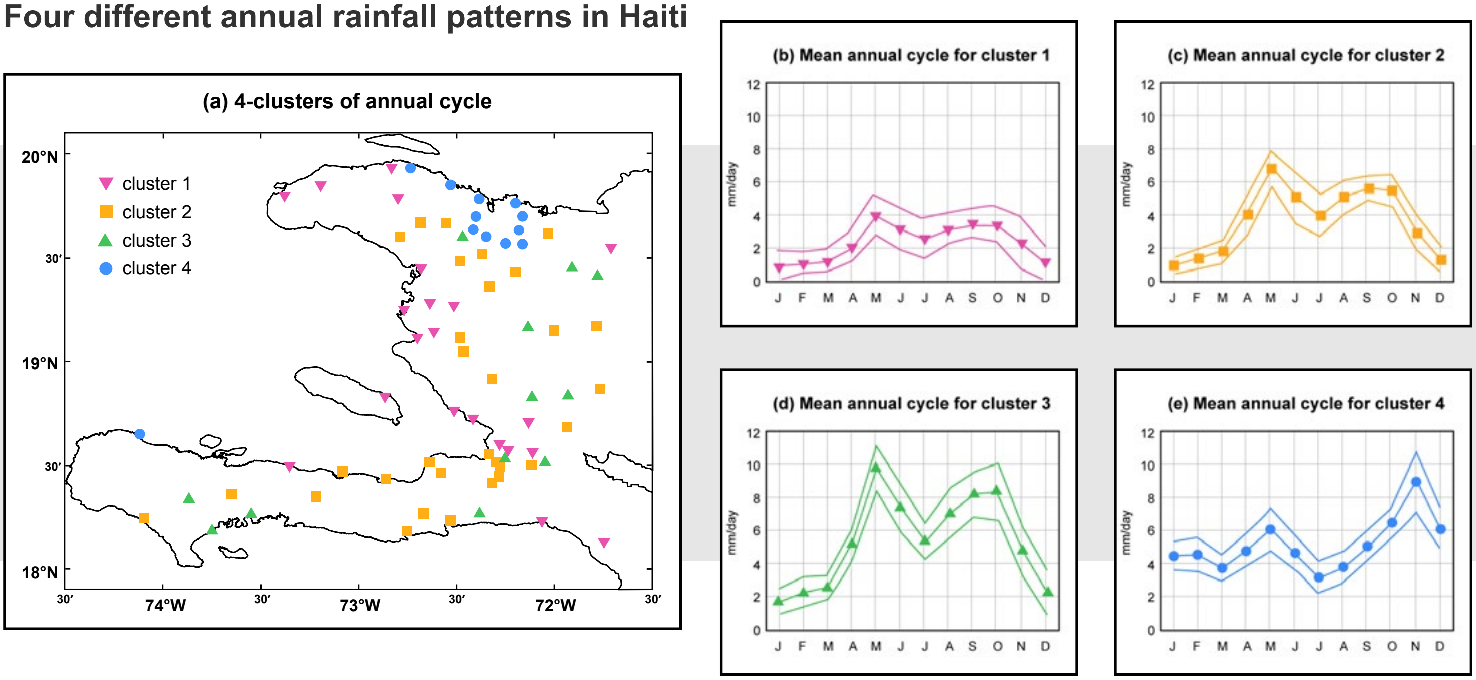
The *Plaine du Gonaïves* and the eastern part of the *Plaine du Cul-de-Sac* are the driest regions in the country. The wet season in Haiti is long and is characterized by two pronounced peaks (bimodal) typically occurring around May and October-November.







Four different annual rainfall patterns in Haiti



CLIMATE OF HAITI

OBSERVED AND PROJECTED CLIMATE CHANGE TRENDS

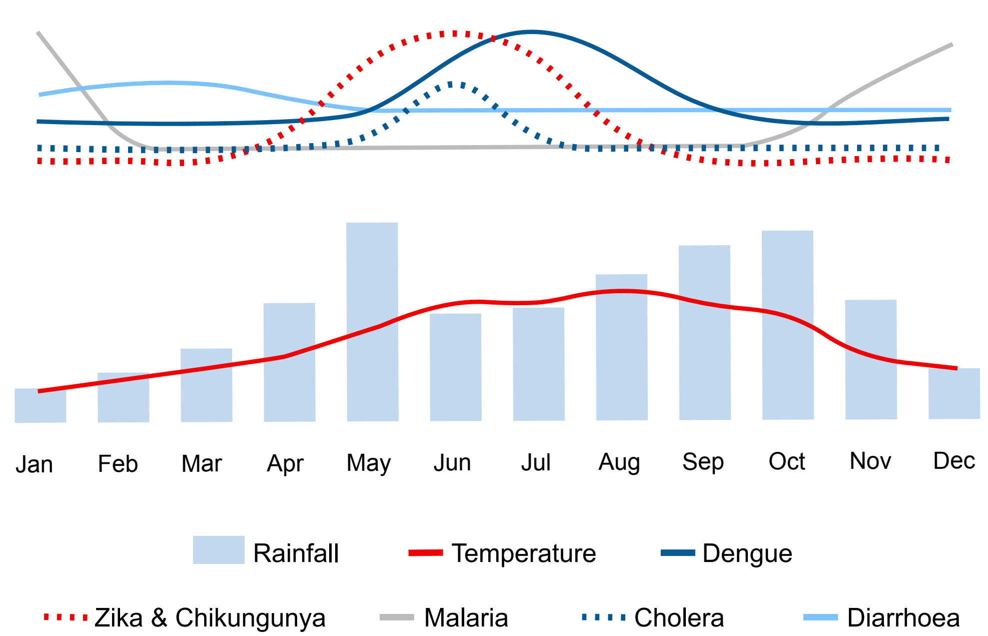
(WORLD BANK CLIMATE CHANGE KNOWLEDGE PORTAL)

- Mean temperatures have increased by 0.45°C since 1960, with warming most rapid in the warmest season, June-November. Under current intermediate climate change scenarios (SSP2-4.5), by 2040 Haiti is projected to become around 0.5°-0.75°C warmer on average.
- Mean annual rainfall has decreased by 5 mm per month per decade since 1960. Under current intermediate climate change scenarios (SSP2-4.5), by 2040 Haiti is projected to have slightly lower rainfall (average 4mm) during the early rainy season but slightly higher rainfall (average 11mm) during the late rain peak.
- Haiti is particularly vulnerable to extreme weather, and the intensity of Atlantic hurricanes has increased substantially since 1980.
- The Nord-Ouest, Artibonite, Nord-Est, and Centre departments frequently experience repeated droughts, brought about by a combination of erratic rainfall patterns coupled with limited water management infrastructure.

INTERANNUAL VARIABILITY

Synchronous relationships between Haitian rainfall and sea surface temperature are weak, overall. Even if these relationships are relatively stronger in boreal summer and January it suggests poor potential predictability of seasonal rainfall anomalies from sea-surface temperatures.

Annual weather and seasonality of focus diseases in Haiti



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BRIEFING

MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

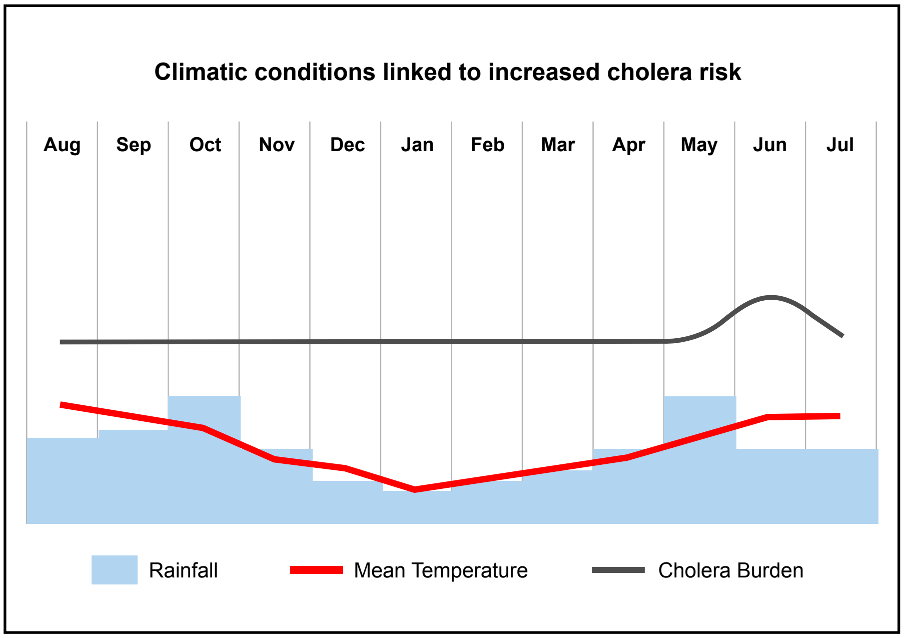
CHOLERA IN HAITI[1]

Cholera is a waterborne disease caused by the bacteria *Vibrio cholerae*. Analysis of the spatio-temporal dynamics of cholera in Haiti reveals 3 major peaks, in November 2010, June 2011 and June 2012 respectively. The first was marked by cholera transmission along the Artibonite River, the second mainly in mountainous regions and the third characterized by a heterogeneous distribution.

From 2013, the epidemic was characterized by a stagnation in the incidence of suspected cases, which fell drastically in 2017. The last confirmed case of cholera dates to February 2019, in the commune of L'Estère in the department of Artibonite.

SPATIAL DISTRIBUTION AND SEASONALITY

With no cholera cases reported in Haiti since 2019, current seasonality cannot be described. However, following the initial outbreak in 2010 (which commenced in November of that year amongst an immune naïve population following an external introduction), peaks in cholera cases have occurred in June, coinciding with the first peak in rainfall.



OVERVIEW OF LINKS BETWEEN CLIMATE VARIABLES AND CHOLERA

Studies suggest rainfall can be used as an indicator: approximately a 40% increase in cholera incidence can be forecasted by either 100mm cumulative rainfall in any 3 weeks after a 6-day lag or by 10mm rainfall above weekly average after lag of 4 weeks. Temperature can also be used as an indicator, over longer lag times. A simple model may be based on the principle that 2 months of above average temperatures followed by 1 month of above average rainfall produce conditions for high risk of cholera outbreak.

Cholera is related to both weather variability and extreme weather events, particularly through episodes of high rainfall. Given the potential environmental source of cholera in sea water, in endemic settings climate variability and change may also influence incidence. However, the specific relationships between these factors and cholera incidence in Haiti have not been well studied. Additional modelling on this topic is required.

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CHOLERA IN HAITI

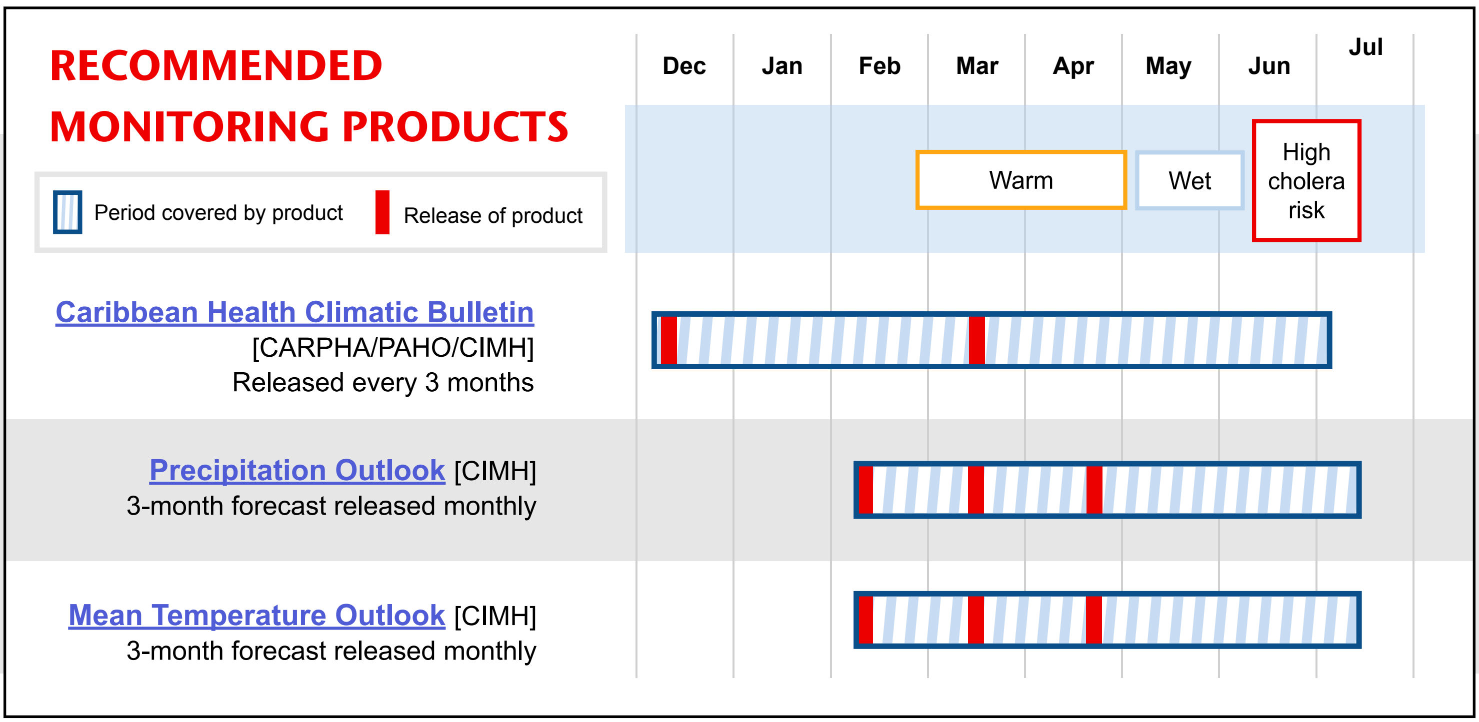
RECOMMENDED INDICATORS

Evidence suggests the following environmental indicators could be useful for forecasting cholera:

- *Weekly mean temperature*
- *Weekly total precipitation*

Assessment of temperature, rainfall, and risk should be done at a local level, to account for local environmental conditions and prevailing average temperatures. The size of the lagged effect of temperature and rainfall changes on risk of cholera outbreak requires further assessment using data from Haiti to be reliably used in forecasting for public health decision making.

These indicators are intended to be illustrative and indicate where further modelling would be useful.



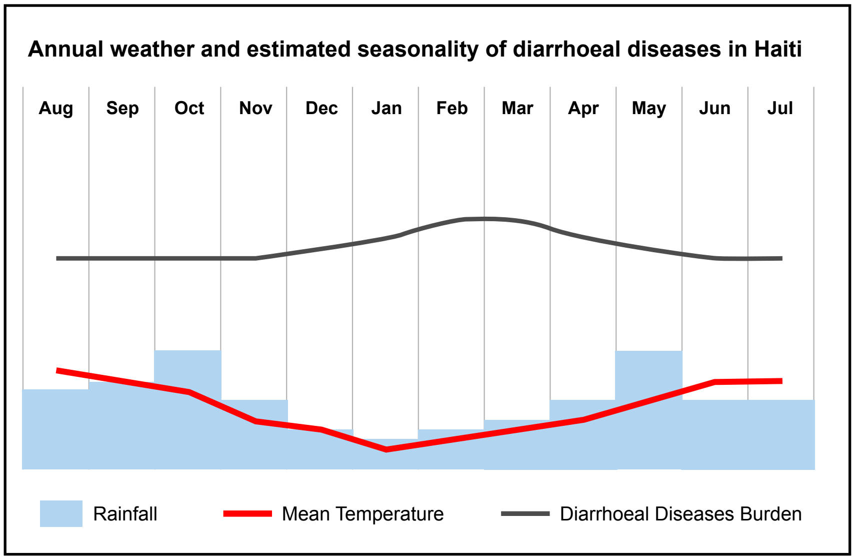
BRIEFING

NON-CHOLERA DIARRHOEAL DISEASES IN HAITI[1]

Diarrhoeal diseases in Haiti, commonly caused by rotavirus although also due to bacterial (including *Shigella, E. coli,* and *Salmonella*), parasitic (*Cryptosporidia*), or other viral sources, are a source of significantly morbidity and mortality: studies have shown among children diarrhoeal diseases are responsible for around 26% of hospitalisations and 13% of deaths. Data are insufficient to draw conclusions on the spatial distribution of diarrhoeal diseases, however it is known that these will be more common in the absence of adequate clean water and sanitation.

SPATIAL DISTRIBUTION AND SEASONALITY

The incidence of hospitalisations and deaths from non-cholera diarrhoeal diseases has been shown to be highest in January to April in Haiti, the coolest and driest period of the year. This is a consequence of a high burden from rotavirus in Haiti during these months, which, in contrast to other causes of diarrhoea including parasitic and bacterial, has been associated globally with low temperatures and rainfall.



OVERVIEW OF LINKS BETWEEN CLIMATE VARIABLES AND NON-CHOLERA DIARRHOEAL DISEASES

Diarrhoeal disease caused by bacterial or parasitic pathogens (in Haiti likely to be *Escheria coli, Cyclospora*, or others) are expected to have a higher incidence in the rainy season. However diarrhoeal disease caused by viral pathogens, particularly rotavirus which is the most common cause of diarrheal disease in Haiti, is expected to increase in colder, drier months. These associations have not been well studied in Haiti, and more data and modelling are required. For this reason, under both optimistic and pessimistic climate change scenarios, deaths from diarrhoeal disease are forecasted to decrease in the Caribbean region over coming decades, because of warmer temperatures limiting the impact of viral pathogens.

RECOMMENDED INDICATORS

Due to the lack of available evidence for Haiti, it is not possible to recommend the use of weather or climate indicators to forecast diarrhoeal disease incidence in Haiti. More data and modelling are required.

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BRIEFING

MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

MALARIA IN HAITI[1]

Malaria is a parasitic disease caused by the genus *Plasmodium* (mainly *Plasmodium falciparum* in Haiti, although possibly also *Plasmodium malariae*). It is endemic in the Caribbean region only in Haiti and the neighbouring Dominican Republic.

The prevalence of malaria in Haiti is 5%, or about 50,000 cases per year, and women and children are most exposed to complications including cerebral malaria and multi-organ failure. Malaria is one of the top ten causes of morbidity and mortality in Haiti, making it one of the main national public health problems. Around 80% of the population of Haiti are at risk of malaria, generally those living below 300m.

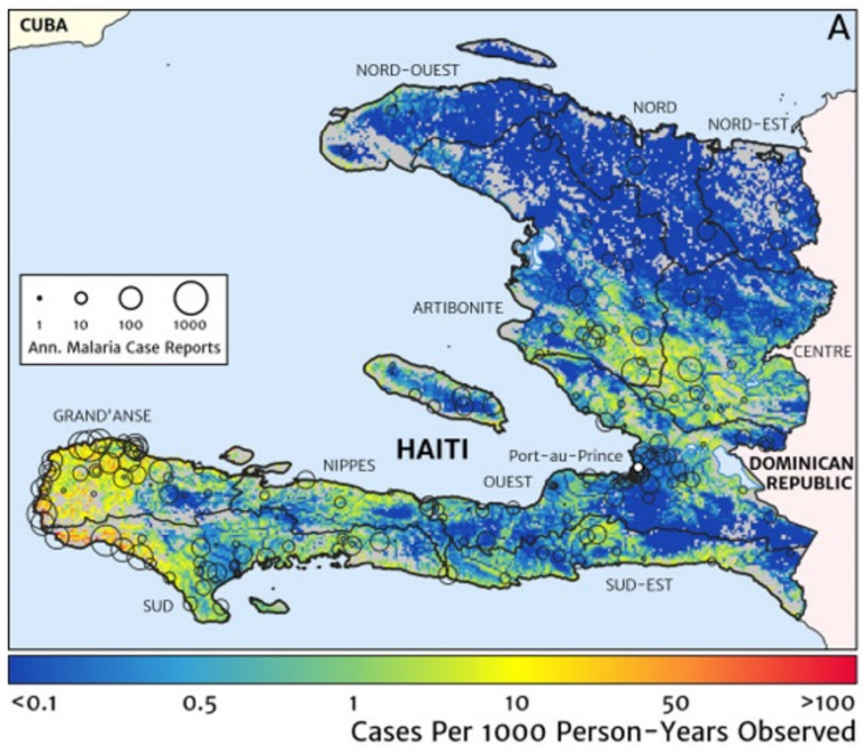
A recent study showed there were approximately 232,000 (MSPP figure) and 303,000 (WHO figure) confirmed malaria cases in Haiti from 2009 to 2018, a discrepancy which reflects the poor data on this disease in this setting. From 2009 to 2018, annual incidence has decreased by around 80%.

SPATIAL DISTRIBUTION AND SEASONALITY

Sud and Grande Anse experience the highest malaria burden, and generally coastal areas are most vulnerable, however malaria is present in all Departments.

Despite the importance of malaria as cause of morbidity and mortality in Haiti, there is little evidence on the seasonality of malaria. One study described a rise in cases during October-November with a peak in December-January then declining rapidly from February to a low during April-May across most of the country, most notably the central valley. This increase follows the second peak in rainfall, and is a different pattern than for dengue which rises after the first peak in rainfall.

Spatial distribution of malaria burden in Haiti **(2014-2019)** [2]



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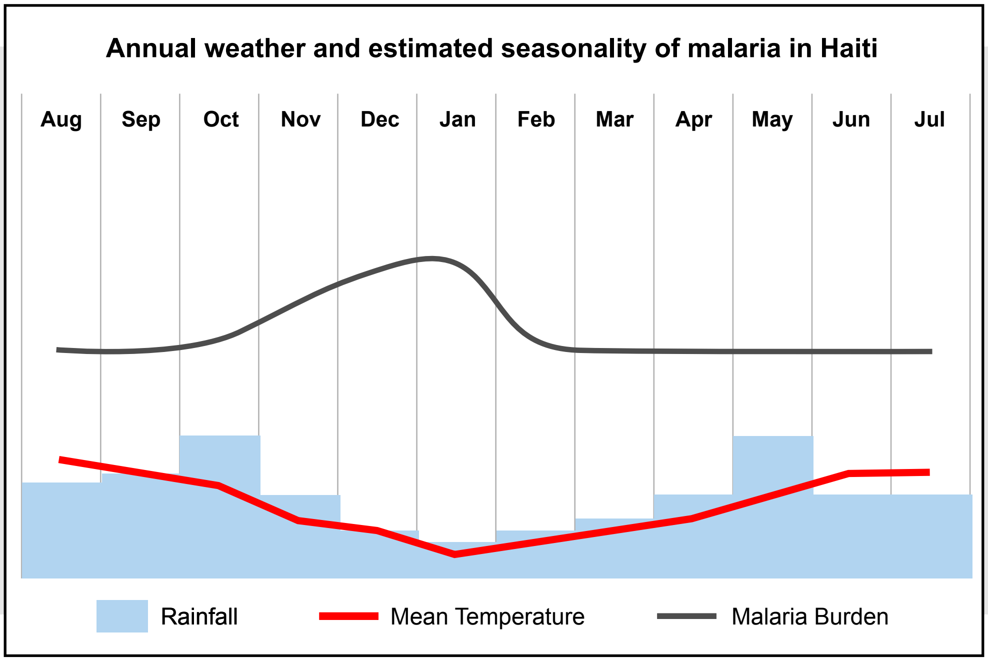
[2] From Cameron et al, 2021

MALARIA IN HAITI

OVERVIEW OF LINKS BETWEEN CLIMATE VARIABLES AND MALARIA

One study from Haiti showed that in the high incidence areas of the Artibonite valley and the Grande Anse department, an increase in the vegetation, measured by satellite as the enhanced vegetation index (EVI), was the strongest predictor of increased malaria incidence with a lead time of 2 months. Vegetation itself is an indicator of prevailing temperature and rainfall. Increasing temperature was the strongest predictor of increasing malaria incidence with a lead time of 1 month in colder highland areas. Broadly, in the areas where EVI was a positive predictor, temperature was negative predictor at 1 month lag.[3]

Under current climate change scenarios, the weather in Haiti is projected to become warmer, therefore higher altitude areas, currently free from malaria, are likely to become suitable habitats over coming decades.



RECOMMENDED INDICATORS

Due to the lack of available evidence for Haiti, it is not possible to recommend the use of weather or climate indicators to forecast malaria incidence in Haiti. More data and modelling are required.

[3] From Cameron et al, 2021

BRIEFING

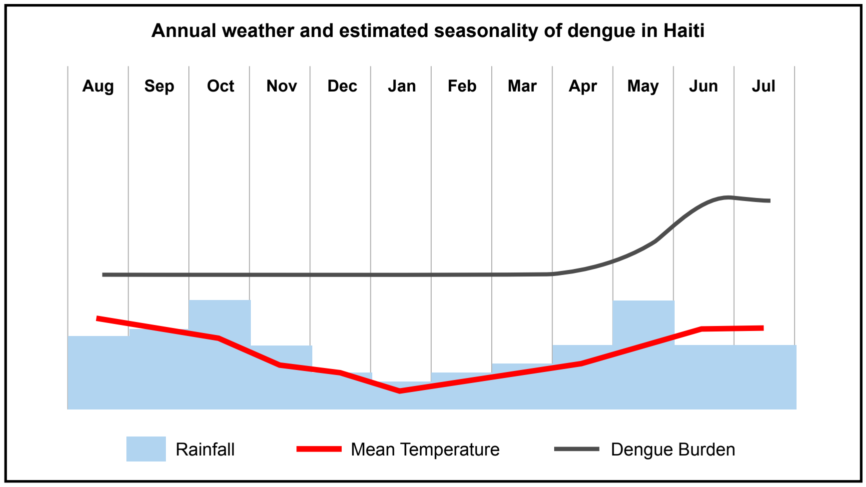
DENGUE IN HAITI[1]

Dengue virus (DENV) is transmitted to humans through the bite of an infected *Aedes* mosquito, principally *Aedes aegypti* or *Aedes albopticus*, which are both present in Haiti. All four DENV serotypes are circulating in Haiti, and the disease is endemic. Due to the involvement of vectors in transmission, and an association with water storage, dengue is a climate sensitive disease.

SPATIAL DISTRIBUTION AND SEASONALITY

Due to the low number of dengue cases detected in Haiti, it is not possible to identify a seasonal dynamic or a spatial distribution of the disease using national surveillance data. To have an idea of the potential spatial distribution of the disease and its seasonality, we chose to use epidemiological information from a similar context, neighbouring Dominican Republic, as the climate is similar, both Aedes vectors are also present and all DENV serotypes can also be found.

Generally, although cases of dengue occur year-round, higher incidence and outbreaks occur in the later part of the year (from June to September) following a pattern of warming, then increased rainfall, then a rise in cases. In Dominican Republic, dengue occurs with greater intensity between the months of June and October, in the rainy season. The risk of dengue is thought to be present at elevations below 2,300 m. Transposing the same threshold in the Haitian context would mean that the dengue risk is present everywhere on the territory, save for Haiti's highest peaks Pic La Selle and Pic Macaya.



OVERVIEW OF LINKS BETWEEN CLIMATE VARIABLES AND DENGUE[2]

Weather: Vector abundance is linked to **temperature,** as increasing ambient air temperatures decreases gonotrophic cycle length up to a maximum above which the vectors will not survive. A minimum temperature is also required for mosquito development. The typical temperature range in Haiti is suitable for vector development year-round, however increasing temperatures with the onset of rains lead to an increased number of vectors over the boreal summer. The 27°-29° C temperature range appears to be an optimum for mosquito development, therefore minimum monthly temperatures approaching this value are a signal for increased dengue incidence with around a 2-3 month lag. The impact of increasing temperatures is greater in cooler areas.

Vector abundance is linked to **rainfall**, as rainfall is required to create breeding sites. High rainfall may wash away small breeding sites. Drought may lead to increased use of artificial water storage, which conversely may also increase vector abundance. With rainfall, the relationship follows a non-linear pattern influenced by use of water containers or localized flooding. Generally, increased monthly rainfall must occur to trigger increased dengue incidence with a lag around 2 months. *[Continued on page 2]*

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MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

DENGUE IN HAITI

RECOMMENDED INDICATORS

Evidence suggests the following environmental indicators could be useful for forecasting dengue:

- *Monthly minimum temperature*
- *Monthly total rainfall & standard precipitation index*

Assessment of temperature, rainfall, and risk should be done at a local level, to account for local environmental conditions and prevailing average temperatures. The size of the lagged effect of temperature and rainfall changes on incidence requires further assessment using data from Haiti to be reliably used in forecasting for public health decision making. These indicators are intended to be illustrative and indicate where further modelling would be useful.

CLIMATE VARIABLES AND DENGUE [CONT'D]

Drought conditions at 5 months lag followed by intense rainfall can be interpreted as signs of an imminent outbreak.

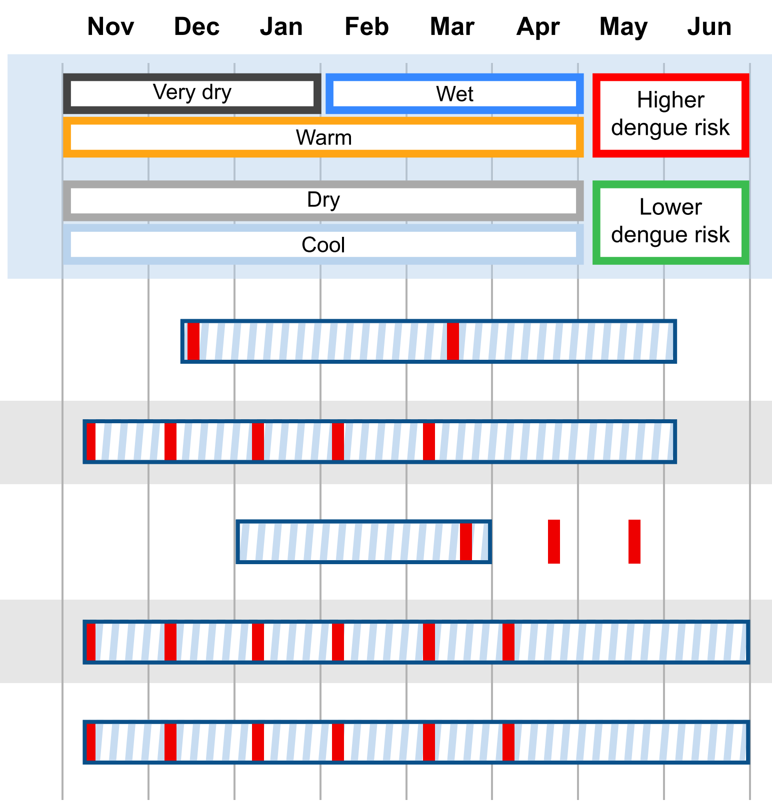
Extreme weather events: Global literature linking extreme weather events to dengue shows high evidence overall that drought conditions increase the risk of dengue outbreaks and medium evidence for heavy rains increasing dengue outbreak risk. There is a low level of agreement amongst studies regarding the impact of tropical cyclones (hurricanes) on dengue.

Climate variability: Multi-year climate phenomena, such as the El Niño Southern Oscillation (ENSO), have an influence on the prevailing weather: there is no clear evidence of an association between ENSO and dengue incidence in Haiti.

Climate change: Under current climate change scenarios, the weather in Haiti is projected to be warmer, with decreased rainfall. It is likely the dengue season will occur earlier with more cases.

RECOMMENDED MONITORING PRODUCTS

Period covered by product | Release of product



Caribbean Health Climatic Bulletin
[CARPHA/PAHO/CIMH] Released every 3 months

Drought Outlook [CIMH]
3-month forecast released monthly

SPI Monitor [CIMH]
Retrospective released monthly

Min Temperature Outlook [CIMH]
3-month forecast released monthly

Precipitation Outlook [CIMH]
3-month forecast released monthly

[2] Note studies from other settings not directly applicable to the Haiti context: Cuba, Jamaica, and Dominican Republic share a similar climate. Puerto Rico has a similar temperature profile with a less pronounced bimodal rainfall pattern, and more rainfall overall. Lesser Antilles typically have a single rainfall peak occurring later in the year and are warmer on average, therefore different seasonality of dengue. Principles of the impact of environmental indicators on vector dynamics are, however, generally applicable across contexts.

MEDECINS SANS FRONTIERES
DOCTORS WITHOUT BORDERS

CHIKUNGUNYA AND ZIKA IN HAITI[1]

Chikungunya (caused by the alphavirus CHIKV) and Zika (a flavivirus) are viral diseases transmitted by mosquito bites of *Aedes* species, like dengue, and considered alongside dengue as arboviruses.

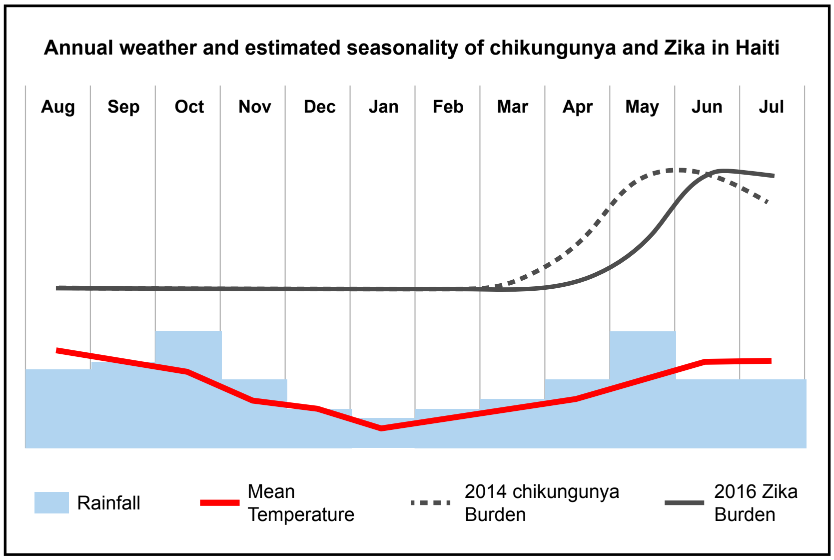
Following initial outbreaks of these emergent diseases in 2014-2015, the Caribbean has experienced low transmission, with no recent cases reported in Haiti (last cases reported in 2019).

The chikungunya epidemic affected Haiti in 2014, where 3,460 cases were reported. The most affected departments were the Ouest, Nord-Ouest and Sud-Est accounting for 65%, 12% and 10% of reported cases, respectively. Major spikes in the epidemic were detected in June, October and November 2014, and January 2015, although studies suggest a complex picture of co-infection by various arboviruses.

Zika virus disease was retrospectively detected in Haiti in December 2014, although the first cases were reported in October 2015. From October 2015 to September 2016, 3,036 suspected cases were reported. The most affected departments were the Ouest, Nord, and Centre with 35%, 19% and 14% of reported cases, respectively. Two further outbreaks occurred in early 2016 affecting the communes of Plaine-du-Nord, Milot, and Fonds-des-Nègres. Following the initial peak, cases have declined, with either low or no detected transmission in recent years.

SPATIAL DISTRIBUTION AND SEASONALITY

Data for chikungunya and Zika are insufficient to show these diseases are endemic, therefore seasonality and current distribution cannot be described. The chikungunya outbreak in Haiti in 2014 was characterised by an increase in cases in May and June (earlier than for dengue) with a mixed pattern for Zika in 2016, occurring in the first half of the year although the initial outbreak was in October.



OVERVIEW OF LINKS BETWEEN CLIMATE VARIABLES AND CHIKUNGUYA AND ZIKA

Whilst chikunguya and Zika are transmitted by Aedes mosquitoes, it cannot necessarily be assumed that the incidence of these diseases will be influenced by climate and the environment in the same way as dengue. Data from Dominican Republic has shown that Zika and chikungunya, as emerging viruses, do not conform to the same outbreak dynamics as dengue, with their timing influenced strongly by the size of the susceptible population rather than optimum weather conditions. Previously, peaks in Zika and chikungunya incidence occurred earlier in the year than dengue, concurrent with increasing transmission potential, whereas dengue peaks at the peak of transmission potential defined by the weather.

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CHIKUNGUNYA AND ZIKA IN HAITI

RECOMMENDED INDICATORS

Currently, it is not possible to recommend the use of weather or climate indicators for forecasting the risk of chikungunya or Zika in Haiti. Additional studies modelling these associations are recommended.