Is Satellite Data Right for Your Needs?

HUMANITARIAN DECISON-MAKING GUIDE

DISEASE RISK

LIFELINES

Table of Contents

Acknowledgements

Lead Author: Maia Tarnas | NASA Lifelines Senior Fellow
Supporting Author & Report Design: Seamus Geraty | NASA Lifelines Community Tools Lead

We are grateful to the individuals in our working group, each of whom helped guide the creation and development of this case study: Aula Abbara, Eric Anderson, Naser Almhawish, Mahin Al Nahin, Jo Belanger, Andy Boyd, James Brown, Helena Chapman, James Colborn, Amber Dismer, Tom Handzel, Faiza Rab, Rohini Sampoornam Swaminathan, Michelle Schmitz, and Alberto Sibileau.

We'd also like to extend a special thanks to our NASA Lifelines colleagues: Caroline Crystal, Emma Curtis, Sophie Hayes, Brian Perlman, Jeff Pituch, and Barira Rashid.

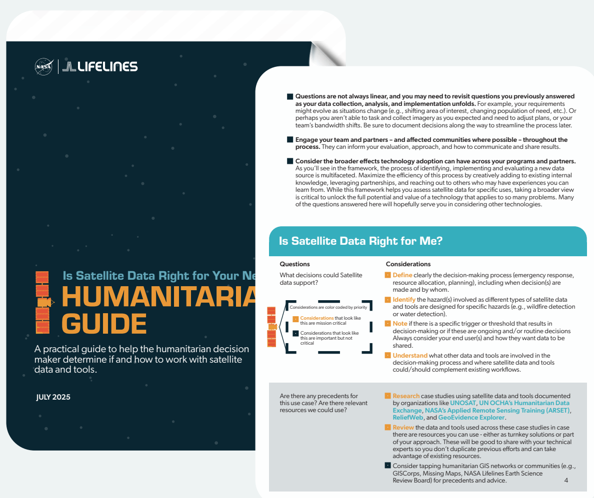
Introduction

Conditions in humanitarian contexts are often primed for the spread of infectious diseases. Pathogens thrive in environments with displacement, limited infrastructure, and poor living conditions. They are also highly responsive to the natural environment; factors including rainfall, temperature, flooding, land cover, and humidity can influence disease dynamics. Some changes can also result from human action; for example, when water, sanitation, and hygiene (WASH) infrastructure are damaged, more water and sewage may pool in residential areas. These factors are interconnected and may result in compounded risks and outcomes.

As several parameters that modify disease risk can be detected or monitored by satellites, Earth observation (EO) data offers a useful tool for risk mapping. This is especially true if satellite data and tools can be linked with health data and inform anticipatory action or other response efforts. These tools can help users understand which areas may face increased risk based on factors like flooding, building damage, poor healthcare access, or extreme heat. They can also be used across a variety of outcomes, including water-borne diseases, vector-borne diseases, neglected tropical diseases, or vaccine-preventable diseases. **Appendix A** includes examples of how EO can contribute to specific goals related to disease risk mapping and response.

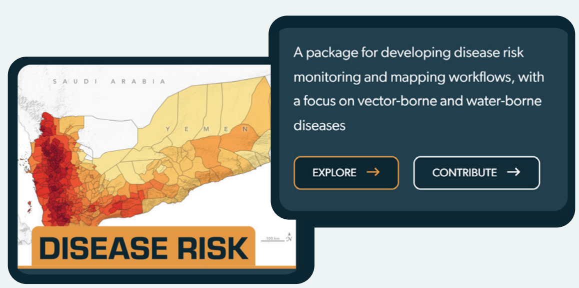
As you explore whether EO is a useful tool for your use case, it is important to first understand and articulate the outcome you are interested in monitoring or mapping. Being clear about the desired outcome may help develop clear definitions of the "risk(s)" of interest: specifically, the risk of what (e.g., disease incidence or a particular hazard) and to what or whom (e.g., the general population, subpopulation, or to a system like healthcare operations).

This case study supplements the **EO Humanitarian Guide**, published by NASA Lifelines in July 2025, and applies the guide's **Suitability Assessment Framework for Satellite Data**. The framework walks through a structured set of questions to help end users determine whether satellite data is fit for purpose, as well as considerations for how to integrate EO data into workflows. This case study is designed for **humanitarian decision makers** who recognize the value of data-driven approaches but may not have deep technical expertise in remote sensing or geospatial analysis.



Click Me!

This case study is accompanied by a companion **Disease Risk Data Studio Package**, which focuses on environmental monitoring applications. While this report focuses on the analytical and decision-making framework, the Data Studio Package provides hands-on guidance for accessing and working with specific datasets and tools.



Click Me!

In this case study, we highlight cholera and malaria risk given their prevalence in humanitarian contexts. Cholera, a diarrheal disease caused by *Vibrio cholerae*, thrives in humanitarian contexts and its emergence often indicates the breakdown of public health. It is both highly preventable and highly treatable but can spread quickly and devastatingly without access to adequate WASH and treatment. In addition, there were almost **263 million malaria cases** globally in 2023, and **nearly two-thirds** of the 108.4 million people forcibly displaced by humanitarian emergencies live in malaria-endemic regions. Malaria is caused by the *Plasmodium* parasite, which is spread to humans via the bite of infected mosquitoes. This case study includes callout boxes that give specific examples of applying satellite data and tools to these diseases but note that these tools can be used more broadly to estimate risk from other infectious diseases.

A useful framework for thinking about disease risk comes from the Intergovernmental Panel on Climate Change (IPCC), which identifies hazard, exposure, and vulnerability as the three core determinants of risk. Applying this lens to disease risk mapping helps clarify both what satellite data can detect and where gaps remain. Importantly, composite risk scores are most actionable when they remain decomposable into these individual categories, as each call for a different type of response (e.g., two areas with identical hazard levels can face very different outcomes depending on their vulnerability). Vulnerability itself can shift rapidly based on response capacity, making near-real-time data especially valuable. For cholera and malaria, some questions include:

	Malaria	Cholera
Hazard	Is the mosquito vector present in the area?	Is there *V. cholerae* in the local environment?
Exposure	Are people exposed to mosquitoes at home or at work? Are they acutely exposed as a result of another hazard (e.g., temporary shelters post-evacuation)?	Are people exposed to contaminated water at home or at work? Are they acutely exposed as a result of another hazard (e.g., temporary shelters post-evacuation)?
Vulnerability	Can people access treatment and preventive measures (e.g., bed nets)?	Is oral rehydration solution available in local health facilities? Is there poor access to household-level drinking water?

Is Satellite Data Right for Me?

This section aims to help decision-makers determine whether EO data could be a good fit for the disease risk mapping they intend to carry out. The questions below walk through what decisions EO could inform, existing precedents, associated ethical and risk considerations, and examples of what specific EO data could support different applications. Working through this section can clarify whether and how EO could add value to your project.

What decisions could satellite data support?

Using satellite data and tools to map disease risk can help save lives and reduce the spread of infectious diseases. If we can understand where or when people may be more likely to get sick, we can take action to reduce morbidity and mortality. This could be through:

- Informing anticipatory action
- Enhancing partnership with local health authorities and other actors
- Conducting active case finding and sampling
- Increasing disease monitoring
- Implementing public health outreach and programming
- Positioning, stockpiling, or deploying resources

Keep in mind that each of these decisions has different data requirements and analytical considerations. The best way to prioritize decision-making and understand epidemiological patterns is to partner with local public health officials, humanitarian organizations, or non-governmental organizations (NGOs) working in health response. These groups likely monitor disease trends and have an understanding of epidemiological norms that can be helpful in grounding this work.

Tools that focus on shifting a reactive response to a proactive one are especially valuable, and satellite data can help with this effort. Users should prioritize **anticipatory action** when possible and consider how integrating satellite data and tools can help inform new or existing action plans. Anticipatory action includes three elements: pre-agreed trigger, pre-agreed activities, and pre-arranged financing.

Anticipatory Action Element	Definition	Example
Pre-agreed trigger	Thresholds and decision-making rules based on **impact-based forecasts**	20% of a district is flooded and the population density exceeds 2,000 people per km^2

Pre-agreed activity	Specific actions to be taken after the trigger is met	Provide pre-positioned clean drinking water and chlorine tablets at evacuation sites
Pre-arranged financing	Guaranteed funding that will be released on the trigger for the pre-agreed activities	Release funds to cover activities from earmarked response budget

In this example, satellite data could be used to inform an actionable trigger (such as by determining the critical flood extent, as expressed by percent of area covered or duration, based on historical data) and to assess when that trigger has been met in order to launch activities that limit the spread of water-borne disease in the affected district. Some organizations, like the **Netherlands Red Cross data team**, specialize in developing Early Action Protocols and trigger models in collaboration with International Federation of Red Cross and Red Crescent Societies (IFRC) and other humanitarian actors.

Cholera Risk

Since 2023, the **Anticipatory Action Framework for Cholera in the Democratic Republic of the Congo** has been triggered four times in response to potential outbreaks. During the May 2025 response, the UN Central Emergency Response Fund released US $750,000 to aid 139,000 people in Maniema and Tshopo Provinces. The program defined three thresholds that could activate pre-agreed activities and pre-arranged funding: 1) an anomalous number of suspected cases or deaths over three weeks in an endemic province, 2) a shock, such as flooding, in an endemic province, and 3) an unusual rise in suspected cases or deaths in non-endemic areas. In the lessons-learned report from this work, leveraging environmental data to define thresholds and support earlier response was identified as a future direction; satellite data and tools can help fill this knowledge gap.

Malaria Risk

Médecins Sans Frontières (Doctors without Borders) launched the **Malaria Anticipation Project** in 2021 to see if historical case and environmental data could predict future malaria burden and inform anticipatory action. In a **pilot study** in Jonglei State, South Sudan, the model accurately predicted cases with 2 weeks' lead time and had moderate success up to 8 weeks' lead time. The model collected satellite data and tools from platforms such as Google Earth Engine, Copernicus, and NOAA, and is now being expanded to other geographies and diseases, including dengue.

Are there any precedents for this use case? Are there relevant resources we could use?

Several existing initiatives demonstrate how EO data has been applied to disease risk mapping in humanitarian contexts, offering both proven models and ready-made resources that new efforts can draw from. The **UN Office for Disaster Risk Reduction** has tools and guidelines for reducing the impact of disasters, which could be applied to disease response. Some examples of disease risk mapping in action, especially for cholera and malaria, include:

> The **Disease Incidence and Resource Estimator** (DIRE) from University of California San Diego, United Nation Children's Fund (UNICEF), and New Light Technologies uses machine learning tools to show dengue fever and malaria outbreak trends in Brazil and Peru, as well as predict the number of potential cases in the following month. They use epidemiological, socioeconomic, and environmental data to inform the model, including many open access resources.

> The European Space Agency sponsored the **Waterborne Infectious Diseases and Global Earth Observation in the Nearshore** (WIDGEON) project to monitor the risk of water-borne diseases to humans using EO across India. WIDGEON also integrated capacity building into their work, including **online training courses**.

> Researchers in the GeoHealth & Hydrology Lab at the University of Florida have developed the **Vibrio Prediction Hub**, which predicts cholera risk in parts of Africa, Asia, and Europe. In 2017, international aid groups in Yemen **used this work** to focus their response efforts in areas that needed the most support.

> The **Epidemic Prognosis Incorporating Disease and Environmental Monitoring for Integrated Assessment** (EPIDEMIA) tool combines surveillance and environmental data to predict malaria outbreaks in Ethiopia. The team at University of Oklahoma and Ethiopian public health agencies, NGOs, and universities have made many of their forecasting tools publicly available.

> The Lebanon WASH Sector's 2025 **Waterborne Disease Risk Map** identified 85 regions that are "highly vulnerable" to water-borne diseases. This resource builds on a cholera risk map created in 2022 and adds information on drought vulnerability to data on population, proximity to contaminated sources, WASH services and access, and case trends.

NASA's Applied Remote Sensing Training (ARSET) program also has trainings on **Remote Sensing for Climate-Sensitive Infectious Diseases**, **The Application of Earth Observations for Assessing Waterborne Disease Risk**, **Humanitarian Applications Using NASA Earth Observations**, and **Earth Observations for Humanitarian Applications**, all of which give practical guidance on integrating EO and epidemiology.

What are the ethics and risk considerations of introducing the use of satellite data?

Although there are established relationships between specific diseases, environmental factors, and other parts of the physical environment, satellite data and tools are unlikely to capture true disease dynamics. Communicating these limitations when introducing satellite data can help set the expectation for what these tools can and cannot capture. For example, satellite data cannot show how people interact with each other inside buildings, but it can help us estimate how many people are in an area based on the number and type of structures. Both these population components are epidemiologically important, but there are limitations on what can be gleaned from satellite data.

Earth observations can also identify relevant infrastructure, like hospitals and displacement settlements (or corroborate their locations or extent of an affected area), but these areas may be vulnerable to attacks or other violent action if their locations are widely known. Collaboration with local partners can help determine how to use this data without bringing additional harm to the community. EO can also help put missing populations "on the map," but there may likewise be risks or ethical considerations associated with publicizing their locations.

There are often multiple health events happening at the same time in humanitarian settings, each of which requires resources and personnel. Before using satellite data, consider whether there are sufficient resources for current requirements and this additional task, as well as whether there is a risk of pulling resources away from ongoing or future health responses. Moreover, there is always the risk that poor interpretations of satellite-based analyses can direct attention away from current issues or important progress. Make sure that there is capacity to conduct analyses and communicate findings in a way that prevents unintended error or bias.

What data could support these decisions? What are 'must have' requirements for the data for these use cases? Is commercial imagery or tasking needed? What are our alternatives?

There are several categories of data that could support disease risk mapping. These can be pulled from satellites, existing surveys or databases, and from partners. Where possible, it would be helpful to align the data with **Common Operational Datasets**, which are used across actors in humanitarian response. Relevant data categories include:

- Environmental variables (including extreme events)
- Health surveillance data (e.g., case data)
- Population estimates
- Infrastructure data
- Public health data (e.g., vaccine coverage, food security, etc.)

When compiling data, consider the specific minimum required indicators for the disease of interest and intended use for the work. This will change based on what is being assessed and what outcomes satellite data is informing. Ultimately, working in collaboration with local public health officials or other entities responsible for collecting data and providing health services will be the best way to ensure that the work is useful, grounded in epidemiological realities, and responsive to potential ethical considerations.

The end goal will also help determine which satellite data is best to use, especially when considering factors like revisit time (how often a satellite passes over a particular place) and latency (the time between a satellite acquiring data and when the data is publicly available). If the goal is to monitor an outbreak of a disease that moves quickly, a 5-day revisit time or 3-day latency might make the data outdated by the time it reaches humanitarians. When deciding on specific sources, consider whether the speed of the pathogen outpaces the frequency of data updates, and whether this will limit applicability. You should also consider what spatial scale is most useful; if this work is meant to inform local response efforts, a village-level or household-level scale may be necessary. If the goal is to compare risk across a country, however, analyses at the district level (admin 2) may be more appropriate.

To Consider...

When deciding on specific sources, consider whether the speed of the pathogen outpaces the frequency of data updates, and whether this will limit applicability.

You should first explore the variety of analyses that are possible with open-source data before pursuing commercial data. If you ultimately determine that commercial data is necessary, contact providers directly to ask about eligibility for crisis response or humanitarian access programs, which can often provide imagery at reduced or no cost. Organizations with relationships to the U.S. government or to national disaster management authorities may also be able to access imagery through programs such as the **International Charter on Space and Major Disasters** or others. Likewise, some organizations with academic or university partnerships may also be able to access commercial imagery through education and research programs offered by providers.

Health surveillance data

Ideally, public health partners can provide data on disease cases. If they have historical case data, this can be used to look at long-term trends and deviations from expected seasonal values. In some areas, data may be published online on a dashboard (for example, from the **Global Task Force on Cholera Control**), in a situation report, or through early warning, alert, and response surveillance systems (like in **northern Syria**). Regardless of where the data is from, make sure that its spatial and temporal granularity are appropriate for your desired outcomes. For example, weekly district-level case data may be sufficient for determining regions' risk of having a cholera outbreak, but daily village-level data would be necessary for an actual cholera outbreak response.

Environmental variables

The key environmental variables for your analysis will depend on the outcome of interest. For many diseases, precipitation, temperature, and land cover may be a good place to start, though you should familiarize yourself with the pathogen or vector lifecycle and dynamics to identify "must have" variables. When pulling environmental data, current values and changes from historical averages should both be considered. For example, there may be a lag between the occurrence of heavy rainfall and the emergence of disease cases, so you should pull data from before your study period when possible. It is also important to determine what temporal unit is necessary to reliably capture environmental trends and changes while being realistic about feasibility and other constraints.

Cholera Risk

Temperature and precipitation patterns are both important for the spread of cholera. **Prior risk modeling** in Yemen used daily and monthly precipitation and temperature data to predict cholera risk four weeks in advance with 72% accuracy. If time and resources allow, information on extreme events like flooding or drought could support this initial data.

Malaria Risk

Panama and Honduras have adopted a **malaria forecasting system**, developed by researchers at the Duke Global Health Institute, that uses climate, health, and environmental data to predict where malaria outbreaks may occur up to nine months in advance at the district level. The system includes temperature, precipitation, and land cover changes, as well as data on case numbers and interventions. It is intended to support decision-making related to interventions and response efforts, like test deployment and medication distribution.

When choosing environmental data, the spatial scale should be considered. For example, is precipitation highly variable in your area of interest? Are there extreme elevation changes that modify temperatures within small spatial areas? Below are a few examples of satellite data for relevant environmental variables (you can find more in the **Lifelines Disease Risk Data Studio**).

Environmental Variable	Providers	Temporal Availability	Minimum Spatial Scale	Scale Coverage
Precipitation	IMERG	Half-hourly, daily, monthly	0.1° (11km)	Country
	CHIRPS	Daily, pentad, dekad, monthly, 2-monthly, 3-monthly, annual	0.05° (6km)	Regional
Temperature	MODIS	Daily, 8-day, monthly	1km	Regional
	ERA5-Land	Hourly	0.1° (11km)	Country

Soil Moisture	SMAP	3-hourly, daily	9km	Regional
	GLDAS	3-hourly, daily	0.25° (28km)	Country
Normalized difference vegetation index (NDVI)	MODIS	16-day	250m	Subdistrict
	Sentinel-2 Near-Infrared and Red bands	5-day	10m	Village
Humidity	GLDAS	3-hourly, daily	0.25° (28km)	Country
	FLDAS	Monthly	0.1° (11km)	Country
Land Cover	Sentinel-2 Dynamic World	Near real-time	10m	Village
	ESA WorldCover	2022 and 2021	10m	Village
Flood	MODIS/VIRS Global Flood	Near real-time	250m	Subdistrict
	Global Flood Database	Events 2000-2018	260m	Subdistrict

The **NOAA Global Drought Monitor** and **Google Flood Hub** are appropriate dashboard-based resources for assessing drought and flooding in your area of interest. You can also refer to the **Flooding Decision-Making Guide** and **Data Studio** for more tools and resources, including guidance on the use of synthetic aperture radar for flood monitoring.

Cholera Risk

The **Vibrio Map Viewer**, developed by the European Centre for Disease Prevention and Control (ECDC), uses remotely sensed data on conditions including sea surface temperature and salinity to estimate coastal waters' environmental suitability for *Vibrio* spp., the causative agent for cholera and other vibrioses. This tool can help determine areas where higher levels of Vibrio growth may occur and lead to an increase in disease cases.

Malaria Risk

Deforestation is linked with the risk of malaria, though the direction of change is often context specific. Dashboards like the **Global Forest Watch** can identify how much tree cover loss (and gain) has occurred in a particular area, which may modify individuals' exposure to mosquitoes.

Population Estimates

Knowing the population size is important in understanding disease incidence and the total number of people potentially at risk. This information can be obtained through satellite data (keep in mind that it tends to be modeled), like through **WorldPop**, or local officials may have updated census or information on a specific subgroup. You should also consider whether there are specific groups that face heightened vulnerability to the outcome of interest, such as internally displaced people. Data on these groups may be available from local partners or international agencies (e.g., **International Organization for Migration's (IOM) Displacement Tracking Matrix**), and EO may also be a resource in some instances (for example, in estimating the size of a displacement settlement). There are also some tools, such as the **Climate-Induced Forced Displacement Early Warning** or the **Global Displacement Risk Model**, that try to measure the risk of future displacement based on climate factors and can help inform predictive disease modeling.

Another important metric to consider is the population size in healthcare facilities' catchment area and related travel time. Risk in zones where populations are far from health facilities, thus increasing their vulnerability to severe outcomes of illness, may be higher compared with risk for populations closer to facilities. Health system functionality and resource availability also matter, and systems like Health Resources and Services Availability Monitoring System (**HeRAMS**) can help capture this. Knowing where people are in relation to critical infrastructure – and how many people a single health facility is expected to cover, or whether the facility is functional – will help determine risk and delineate an appropriate response.

Infrastructure Data

Disease risk can be modified by infrastructure related to WASH, healthcare, and housing, as well as people's ability to access that infrastructure (i.e., road quality and conditions). In many instances, information on infrastructure is available from non-satellite sources, such as dashboards or surveys. These should be used as baselines that satellite data and tools can complement, including through gauging functionality or accessibility. For example, local partners may have the locations of hospitals in an area, and satellite data can help assess whether they have been damaged during ongoing conflict. There is more information on measuring building damage in the **Building Damage Assessment Decsion-Making Guide** and **Data Studio**. In conflict-affected settings, databases like **Armed Conflict Location & Event Data (ACLED)**, **Uppsala Conflict Data Program (UCDP)**, or **WHO's Surveillance System for Attacks on Healthcare** can also help identify relevant events.

Some infrastructure already has standards for differentiating risk levels, like the **WHO/UNICEF Joint Monitoring Program's** service ladders for **sanitation** and **drinking water sources**. Following these established classifications can ensure alignment with global standards and allow for integration with other sources.

Indicator	Non-EO Sources
Water, Sanitation and Hygiene (WASH)	UNICEF Multiple Indicator Cluster Surveys
	Demographic and Health Surveys (DHS)
	WASH Cluster
	Multi-Sectoral Needs Assessment (done by multiple agencies, like IMPACT Initiatives or IOM)
Health care facilities	Humanitarian Data Exchange
	Healthsites.io
Buildings and roads*	Open Street Map
	Google's Open Buildings
	GeoPoDe

* See the **Building Damage Assessment Decision-Making Guide** and **Data Studio** for more resources

Cholera Risk

Inadequate WASH infrastructure is a major risk factor for cholera, and in humanitarian contexts, people frequently struggle to access clean drinking water and reliable sanitation. Across numerous countries, health ministries and other organizations are using platforms like **mWater** to map and monitor WASH facilities. This data can complement EO to better understand how WASH availability (or lack thereof) may contribute to cholera risk.

Malaria Risk

People often get bitten by mosquitoes in their homes, especially if the structures are not closed to the outside. Satellite optical imagery can help identify the type of building material used for dwellings in areas of interest. This information can help understand where people may be more likely to get bitten within their homes, which could guide interventions like insecticide-treated bed net distribution.

Public Health Data

Depending on the use case, there are various types of public health data that can contribute to risk mapping. This data could include indicators like vaccine coverage (e.g., through DHS or WHO), bacterial presence (e.g., the **Cyanobacteria Assessment Network**), ongoing humanitarian response efforts (e.g., the **Palestinian Health Cluster**), or One Health indicators (the **Food and Agriculture Organization (FAO) Hand-in-Hand Geospatial Platform**). Food security and malnutrition are also important risk factors for disease, and more information on those can be found in the **Food Security Decision-Making Guide** and **Data Studio**.

Cholera Risk

The **WASH Insecurity Analysis**, led by UNICEF and the Global WASH Cluster, is a structured analytical framework that calculates the relative WASH insecurity score for countries at the admin 2 level. This score is based on four dimensions: 1) WASH service levels, 2) current hazard impacts, 3) future hazard exposure, and 4) WASH-related vulnerabilities. Accounting for WASH-related factors is critical for cholera risk. **The methods** for creating these analyses are clearly documented for reproducibility and transparency, which allows them to be used across contexts including Kenya, Afghanistan, Lebanon, and El Salvador. These reports are notable examples of how to create reproducible and cost-effective structured risk maps geared towards humanitarian action.

Malaria Risk

The **WHO Malaria Threats Map** compiles information on potential biological roadblocks to malaria elimination, including invasive vector species, vector insecticide resistance, antimalarial drug efficacy and resistance, and parasite pfhrp2/3 gene deletions. Data is regularly updated and available globally. When paired with satellite, climate, and health surveillance data, these indicators can help provide a nuanced understanding of malaria risk.

What's our Approach?

This section helps decision-makers design an approach to incorporating EO data into their organization's specific context and constraints. The sections below cover organizational capacity, required resources, and fit with existing solutions. Before working through these questions, users may benefit from conducting a structured assessment of their current programs, capabilities, and infrastructure. This kind of assessment can clarify what spatial data is already being collected or used, as well as any organizational gaps in expertise or guidance.

Do any existing solutions meet our requirements? If not, what gaps exist regarding data access and analysis to support our use case?

There are already risk maps for some diseases in some areas, and depending on your needs, they may meet your requirements. If tools already exist, consider what's missing from those analyses, and whether satellite data and tools can help address this gap. In general, EO should be used to complement existing work or fill its gaps, rather than to re-create existing work.

Cholera Risk

The standard for identifying cholera hotspots is the Global Task Force on Cholera Control's (GTFCC) **Priority Areas for Multisectoral Interventions** (PAMI) approach. PAMI uses four indicators: incidence, mortality, persistence, and test positivity (if possible), and is updated every 1-3 years. Because methods for delineating risk are already in place, think about what gaps EO data can help. For example, the priority indices do not consider how access to health facilities may change an area's risk, and this is an area where satellite data and tools can be useful (for example, to assess road conditions or availability of facilities). Other examples include monitoring population displacement in high-risk areas and tracking relevant environmental conditions.

Malaria Risk

The **Malaria Atlas Project (MAP)** creates publicly available annual estimates of malaria risk and disease burden for *Plasmodium falciparum* and *Plasmodium vivax*, as well as estimates of interventions' coverage. These estimates are available from the global to 5km^2 spatial scales. MAP also provides a **spatial data catalogue** on topics including malaria risk landscape, interventions, vector occurrence, and healthcare access. MAP does not, however, include environmental factors in their risk estimates. You could use satellite data and tools to refine their estimates using factors like precipitation, temperature, and humidity.

In some cases, existing solutions may be incomplete or at an incompatible spatial or temporal resolution for your end use. For example, global tools are unlikely to provide data at the district level, which is often used for Humanitarian Response Planning (HRP). Satellite data can help fill these gaps by modifying or expanding existing knowledge.

Some places already use disease early warning systems, which use an alert threshold to trigger outbreak investigations; these thresholds often vary by disease. Data from these systems can inform your use case, and your use case can in turn supplement the systems. For example, a **standard alert threshold** for acute watery diarrhea (indicative of cholera) may be 5 cases in one week in an area. Use of satellite data could refine this to, for example, 2 cases in one week if precipitation is above a certain level, such as 30mm/week, or another threshold as discussed with public health partners.

What types of skills and expertise are needed? Based on our internal capacity and bandwidth, can our teams take on this work? What kinds of partnerships are needed?

Skills and Expertise

Many humanitarian organizations or local Health Clusters may not have robust in-house geospatial capacity. Depending on the level of technical capability available, you can consider different approaches. For example, it may be more doable to rely on pre-processed products or ready-made tools if capacity is limited to beginner or moderate GIS skills; if there is more advanced expertise, you could work with raw data.

Internal Capactiy	Example Need	Example Approaches
Limited	Estimating Risk	Utilize ready-made tools or partner with external technical support
	Visualizing flood exposure	Use ready-made tools, like NASA Worldview or Google Flood Map
In-house analysts	Estimating Risk	Build a reproducible custom model
	Visualizing flood exposure	Utilize SAR and introduce long-term standing floodwater detection

Skills and Expertise

There are also several components in the geospatial-to-epidemiological translation process that should be considered when approaching this work. In humanitarian settings, health data may be collected at varying spatial resolutions or using administrative boundaries that differ from those used by the WASH Cluster or other organizations. Health data may also be reported using a combination of paper forms, Excel sheets, and electronic records, and cleaning these to align with standardized administrative units that can also be applied to satellite data is critical.

Cholera Risk

If there are team members with experience working on other water-borne diseases, they may be able to transfer their skills to working on cholera, as there are several overlapping environmental risk factors. They may also have insights on specific vulnerabilities that arose in their previous work that should be considered with cholera risk.

Malaria Risk

The same is also true if people have experience working on other vector-borne diseases, and specifically other mosquito-borne illnesses. Though *Anopheles* mosquitoes have unique considerations, a prior understanding of vector-borne disease dynamics (and related vector control in the area) can help in understanding malaria risk.

Internal capacity and bandwidth

Pathogens and vectors move quickly, and there are often existing health response needs that require time and attention. This balance needs to be at the forefront of capacity and bandwidth considerations. Having a clear end goal can help determine the timeline and necessary resources to complete the task. For example, monitoring a flooding event could be short-term if the end goal is to determine the number of people in a high cholera risk area that are immediately affected by flooding. However, continued monitoring of stagnant floodwaters, which can lead to recurring or cyclical outbreaks of disease, may require several months of person-time. You should also consider whether internal resources and bandwidth could support long-term maintenance of a system, or whether a static map would be more appropriate.

It is also worth noting that artificial intelligence can transform how humanitarian actors utilize EO data. Increasingly sophisticated AI models and agents can expand analytical capacity, particularly through rapid analysis of large EO datasets. At the same time, not every GeoAI tool is appropriate for every operational environment, and many tools fall short of technical and ethical safeguards required for responsible use in high-stakes settings across dimensions such as trust, safety, efficacy, equity, and accountability. For further guidance, see NASA Lifelines' **GeoAI for Humanitarian Action** report.

Partnerships

Robust partnerships are critical across every step of this work, including resource sharing, technical expertise, risk communication, and action steps. When deciding who best to partner with, first consider who (or what entity) holds the necessary data for your end goal. This could include case data, information from multisector needs assessments, or detailed census information. You will also need to think about how to access this data (for example, through a health data management system like DHIS2 or via a line list), and whether you will require a data-sharing agreement. It may take longer to access data if it is identifiable.

Local partners can help disseminate results or act on recommendations from these tools. This requires collaboration to establish pre-agreed communication channels and actions based on pre-agreed metrics. Partnering with WASH and Health Clusters can also help introduce tools at a larger scale in your area of interest.

There are also groups that can help support the use of satellite data and tools for disease risk mapping if in-house technical capacity is limited. This includes organizations like NASA Lifelines, the **GEO Disaster Risk Reduction and Adaptation Working Group**, and the **Earth Observation Training, Education, and Capacity Development Network**. These partnerships can support more robust analyses and facilitate capacity-building. You could consider working with a hybrid model, where a technical consultant builds a pipeline to produce outputs that humanitarian actors then operationalize. Keep in mind that the division of labor should be clearly communicated and agreed upon before beginning this work.

Malaria Risk | **Cholera Risk**

Organizations that collect granular data on WASH and other related vulnerability metrics will be important partners. They can also help ensure that the outputs seamlessly integrate with existing workflows and enhance current tools. **IMPACT Initiative's** REACH program, which operates in over 20 countries, is an example of such an organization for cholera analyses.

What data, tools, standards and techniques are already adopted and trusted by humanitarians? What is my team familiar with? How can we know we've covered everything?

Humanitarian actors in your area of interest likely already have tools that they use to assess and report disease risk. Integrating satellite data into these systems can increase trust, communication, and uptake by humanitarians, partners, and communities. This can also help ensure that satellite data and tools are applied in a way that is accessible to humanitarians.

Humanitarian Data Exchange is a foundational hub for data in humanitarian settings, and many organizations will share data there for general use. WASH and Health Clusters are typically also prominent and trusted sources in risk monitoring and health response. To the degree possible, satellite data should extend and be integrated with their existing trusted material. In addition, Mercy Corps' **Reduced Access Analytical Methods Toolkit** offers technical and managerial guidance for working in areas where accessing populations is challenging. This includes guidance on the use of remote sensing, providing another trusted framework for this work.

There may also be standards specific to your area of interest. For example, the **Integrated Disease Surveillance and Response** (IDSR) strategy is the disease reporting system in the WHO African Region. If working in an area that utilizes IDSR, satellite data and tools should be compatible with and feed into IDSR-structured data instead of requiring separate data streams. Similarly, the IFRC uses **Nyss** to support community-based surveillance data collection, management, and analysis.

There are also several internationally recognized data standards that may be relevant, such as the **Integrated Food Security Phase Classification**, which marks the severity of food insecurity and malnutrition within countries. To the extent possible, and as they are relevant, these standards (and any in-country partnerships developed for these processes) should be used.

Cholera Risk

Much of the data, resources, and techniques (satellite-based or otherwise) that are available for cholera or malaria may also be used for other water-borne or vector-borne diseases (and vice versa). Many diseases have overlapping risk factors, and being able to rely on one data source for multiple uses has tangible benefits for trust, capacity, and clarity.

Which data is open and accessible for us and our partners? Who needs access to the data? Any sensitivities on who gets access or when?

Most satellite data and tools for this work are free and publicly available. However, there are several practices that are important to keep in mind when working with health data, including:

- Ensuring that identifiable health information (or even potentially identifiable information) is securely stored. All information should be de-identified and aggregated sufficiently to preserve patients' privacy before sharing.
- Properly separating data so that information cannot be triangulated and used to target vulnerable groups.
- Acknowledging that disease data is often politically sensitive. The origins of the data should be properly assessed before use (e.g., are we missing data from some geographical areas because of the controlling party?) and be prepared for published outputs to face political resistance. Some diseases, such as cholera, are especially politicized.

Because this work will likely involve numerous partnerships, data ownership and use rights should be carefully considered. In some cases, local administrative bodies may not have access to their own data if it is owned or governed by an external entity or another country. Before beginning this work, make sure you are aware of and are following data governance frameworks and ethical guidelines for data sharing, use, and knowledge generation.

Additional guidance is available from the **OCHA Data Responsibility Framework**, the **Berkeley Protocol on Digital Open Source Investigations**, the **Harvard Humanitarian Initiative's Signal Code**, and **ICRC's Handbook on Data Protection in Humanitarian Action**.

What will this approach cost (in people time, time spent, data purchases, travel, etc.)? Is it worth the investment? Are there free/more affordable alternatives?

People-time and time spent will likely be the high-cost areas. However, this time investment can reduce future costs through enhancing preparedness efforts. Costs can also be reduced by utilizing existing data and frameworks whenever possible. Consider what already exists on the outcome and area of interest, what is most needed for health response, and how satellite data can efficiently contribute to this gap in actionable ways.

How much time do you need to gather data? For analysis?

This will largely depend on the project goals, available skills and expertise, and complexity of analysis. Before beginning, determine whether this work will be a one-off analysis or if it will provide continued monitoring or assessment. For either, developing a standardized and reproducible technique is a good way to streamline current and future work. If technical capacity is limited, this can be done by a consultant who develops a standardized methodology that can be implemented and formatted for humanitarian use through open tools with clear documentation and code.

The time required will also depend on how you choose to present results. Outputs should be easy to interpret, require limited expertise, and include recommended actions. These could take several forms, including:

- Static choropleth maps (which use colors or patterns to represent a variable's value across areas on a map)
- Integrated dashboards
- Action-based alerts
- App-based risk maps
- Raster images
- Data tables
- Risk bulletins or situation reports

Make sure to consider whether there is capacity to update these outputs. If not, a well-documented static dataset is often more useful than a stagnant dashboard.

To Consider...

Keep in mind that for humanitarian organizations, the most useful outputs are not necessarily the most complex, but rather the ones that can best translate signals into operational tasks.

What are your needs for analysis like cloud computing, internet bandwidth, team time, other expertise, and in-country partners?

In many humanitarian settings, there may be low bandwidth but high local expertise. Cloud-based approaches (e.g., in Google Earth Engine) can fail due to poor internet connectivity, and approaches that rely on downloading smaller batches of processed data are often more workable. However, a cloud-based approach may be the most feasible for processing large amounts of data which can then be pushed as CSV files or GeoJSONs to field teams. When choosing the analytical approach, consider whether it relies on high-speed data streaming, for example, or whether it can function in an offline-first environment. This is also linked to the work's objective. If you are creating an integrated dashboard for a field team, for example, make sure that it can work on a phone or low-bandwidth setting; if not, a static map may be more appropriate.

Using pre-processed products can reduce computing and technical needs compared to wrangling raw data. There are also online platforms, such as **NASA Worldview** or **FAO Hand-in-Hand Geospatial Platform**, that can be used to visualize satellite data without downloading or storing it. Google Earth Engine, which is free for noncommercial use, is a useful tool for extracting and processing large amounts of data, though it requires steady internet connectivity. If satellite or geospatial data is locally available on computers, **QGIS**, a free geographic information system (GIS) software, or **ArcGIS**, a GIS software from **ESRI**, can be used without internet connection. The balance between data-processing capacity, bandwidth, internet connectivity, and technical capacity should be considered during planning to ensure the project's feasibility given relevant constraints.

There should also be an emphasis on local training and data access. Training opportunities not only increase trust and enhance local expertise, but they also bolster the work's applicability and sustainability. Work that is currently feasible should be prioritized and used to identify areas for skill-building and more robust future work.

Sharing and Communicating Results

This section helps practitioners translate EO analysis accurately and responsibly to inform humanitarian decision-making. The sections below cover considerations for how to characterize the reliability of findings, how to communicate risks and limitations, what elements of an approach should be shared externally, and how to evaluate impact. Given the stakes of humanitarian work, clear and honest communication is essential in outlining assumptions and limitations.

How accurate are the data, analysis, and findings? What is our confidence in this data?

Estimating disease risk is inherently uncertain and may not correspond to exact case numbers. Communicating this uncertainty transparently is an important part of establishing and maintaining trust, especially when the stakes are high. Often, waiting for 100% certainty in your estimates means missing the window for prevention. However, overpromising and getting it wrong can also hinder your ability to operate. Hence, it is important to clearly state the assumptions that underlie the uncertainty and avoid presenting precise case numbers, which create a false sense of accuracy.

Working with organizations and local communities in the field can help ground your work. These groups will likely have a good sense of the local context, including whether risk estimates are realistic. Incorporating feedback and validation loops with these groups during development can make sure you are checking your work along the way, rather than just at the end.

How should we communicate about risks and uncertainty and how to apply data?

Being clear about the level of uncertainty in your estimates is critical when presenting results. You should also consider what balance between specificity and sensitivity is best for your end use. In many cases, it may be preferable to say that there is elevated disease risk and have no outbreak occur than to say that there is no risk and an outbreak does happen. This is not always the preferred balance, however. Properly communicating the concept of risk is also important. Disease risk is the outcome of several interacting components, and this should be communicated clearly and succinctly while still prioritizing action-based messaging.

It is also important to consider how long the risk estimates are good for, especially in the case of seasonal diseases. Similarly, it may be prudent to wait until there is a certain number of days (or weeks) of elevated risk before taking action to ensure the effect is not temporary. This can inform the pre-agreed threshold (or risk level categorization), which should be established early and linked to specific recommendations for humanitarian action. **These recommendations should be explicit and action oriented.** For example, an output that states “Risk of malaria is high. Recommended action: Distribute bed nets in District X by Friday” is more useful than a vague recommendation of “increased vigilance.”

Ultimately, the communication strategy should explain what the outputs mean in operational terms while also conveying the underlying uncertainty. There are several best practices for this strategy:

- Present risk in severity classes or prioritization systems, as decision-makers are used to working with defined categories
- Use confidence intervals or probability ranges rather than point estimates
- Show the relative risk between areas (e.g., risk in Area A is higher than in Area B) or seasonal norms
- Present best- and worst-case scenarios
- Incorporate clear visual data representations that can quickly convey key insights
- Display satellite-derived estimates alongside known or ground-truth data, if available
- Flag areas where satellite-based risk estimation is high but case surveillance is weak
- Identify areas where additional data sources could be used to improve confidence in the estimates (this is also an opportunity to advocate for improved primary data collection)

It is also important to consider who is communicating the results and related uncertainty. When planning this work, decide who will act as the translator between the pixel and the person, and ensure that they can accurately articulate the uncertainty while maintaining trust in the estimates. Keep in mind the stigma that may be associated with labeling a specific area or population as high risk, especially for highly stigmatized diseases.

Are there elements of our approach that should be shared (e.g., lessons learned, data, tools)?

There are several networks and humanitarian platforms where data, tools, outputs, and lessons learned can be shared (be sure to check for security concerns before public release):

- **Humanitarian Data Exchange** is the standard platform for all shareable humanitarian data products. All maps, shapefiles, risk indicators, or tabular data should be published there, if possible, with proper metadata.
- **ReliefWeb** is best for humanitarian situation reports and analytical documents.
- WASH and Health Cluster coordination meetings are the primary venue for introducing analytical products to cluster partners
- If relevant, open code and methodology sharing via GitHub or a similar repository is useful for technical teams who wish to replicate or expand your approach.
- Direct work with communities is an important way to disseminate your findings. This can be through working one-on-one with stakeholders, attending town hall meetings, or conducting home visits.

Cholera Risk

Outputs related to cholera should be shared at **National Cholera Plan** update meetings to ensure they are fed into the planning cycle. Working with organizations like the GTFCC and following their in-country processes throughout this work ensures that it can be integrated into systems that are already established and trusted in humanitarian settings.

Malaria Risk

Similarly, many countries will have their own **national malaria plans** that are often supported by the World Health Organization. Consider how you will integrate and align with these plans, including pathways for data sharing and communicating outputs.

Supporting countries' **Early Warning Alert and Response Systems** is another way to integrate this work into existing tools. These systems rapidly detect outbreaks in humanitarian settings, and the inclusion of validated risk maps could feed into their anticipatory action protocols. Similarly, integration with health management systems like **DHIS2** for routine surveillance could be another avenue to explore.

While it is important to know (and share) which satellite data and tools were the most useful for this exercise, it is equally important to know which did not work. Factors like precipitation, temperature, and infrastructure interact with pathogens in complex and heterogeneous ways that vary across time and space. Approaches that work in some areas may not work in others, and sharing these lessons learned is important for finding the right methods to use.

What was the impact of our decision-making using this data/analysis?

Risk maps can be validated with case counts (including retrospectively analyzing disease cases using satellite data and tools to inform future risk predictions), resource deployment, or increased public health prevention measures.

In retrospect, would we use satellite data again? What do we want to do differently next time?

It is important to regularly assess whether satellite data and tools are capturing disease dynamics with enough sensitivity and specificity to validate their use in humanitarian contexts. To reflect, consider the following questions:

1. Did we capture the right processes?
2. Were the spatial and temporal scales used appropriate for the end goal?
3. Can we better align with ongoing health responses?
4. Did our analysis add to what existing tools were already providing, and if so, how?
5. Did we communicate uncertainty sufficiently?

Conclusion

Disease outbreaks in humanitarian settings can cause large-scale morbidity and mortality, especially among the most vulnerable. EO data offers another tool for users to understand where people may be at risk, how and when resources can be deployed, and potential future case burdens, among other end uses. These tools are especially valuable for their ability to complement existing work and fill its gaps, including through monitoring dynamic environmental conditions and changing circumstances on the ground. They are best utilized in collaboration with partners that can guide its use, application, and communication, and with whom dynamic feedback loops can be established to ensure alignment, feasibility, and sustainability.

These outbreaks often emerge in complex environments alongside other challenges such as armed conflict, displacement, food insecurity, and natural hazards. NASA Lifelines provides additional Decision-Making Guides and Data Studio Packages that address other humanitarian applications of satellite data, including **food security**, **building damage assessment**, **flooding**, **wildfire**, and **landslides**, among others. Practitioners working at the intersection of these areas may find these resources useful for designing integrated analytical approaches.

Earth observations should be considered as a tool that works best in collaboration with local and ground-based knowledge, and in partnership with trusted entities that deeply understand the context. The data from EO is only as good as its communication, and especially how well the information can be translated into operational tasks and recommendations. Ultimately, the success of EO in humanitarian work should be measured not by technical benchmarks alone, but by whether it tangibly benefits the populations it is intended to serve.

LIFELINES

Appendix A: Example Use Cases

Earth observations can contribute to disease risk mapping and response in numerous ways. The table below provides some specific examples, though it is non-exhaustive and meant to illustrate the range of applications for satellite data and tools.

Goal	EO Role	Key Data Sources **Non-EO sources*	Desired Frequency
Predicting malaria cases in endemic areas	Monitoring weather patterns	▪ Precipitation data ▪ Temperature data ▪ Historical cases*	Weekly
Monitoring mosquito breeding sites after flooding	Detecting surface water accumulation	▪ Flood extent ▪ Surface water data ▪ Land use land cover ▪ Population	Weekly
Monitoring access to healthcare facilities	Assessing road quality and infrastructure damage	▪ High-res optical imagery ▪ Land use land cover ▪ Population ▪ Catchment areas*	Monthly
Identifying locations for bed-net distribution	Locating villages with high mosquito exposure risk	▪ Land use land cover ▪ NDVI ▪ High-res optical imagery	Seasonally
Targeting indoor spraying campaigns for malaria	Characterizing settlement patterns and building density	▪ High-res optical imagery ▪ Population ▪ Building footprint data ▪ Land use land cover ▪ Prior spraying coverage*	Annually
Determining high-risk zones for cholera outbreaks	Assessing environmental factors and access to care	▪ Population ▪ Healthcare facility locations ▪ Infrastructure and roads ▪ Environmental data ▪ WASH functionality* ▪ Disease cases*	Annually

Refining surveillance alert thresholds for acute watery diarrhea	Modeling relationship between rainfall and case numbers	▪ Precipitation data ▪ Surface water data ▪ Historical cases*	One-off
Setting a trigger for diarrheal disease response in a flood zone	Determining the flood extent for the trigger	▪ Population ▪ Historical flood maps	One-off