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Space technology and public health

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Health and climate

Health and climate have been linked since antiquity. In modern times, our increasing capabilities to detect and predict climate variations coupled with mounting evidence for global climate change, have fueled a growing interest in understanding the impacts of climate on human health, particularly the emergence and transmission of infectious disease agents.

Environmental Condition	Disease Favored	Evidence
Warm	MALARIA, DENGUE	Primarily tropical distribution, seasonal transmission pattern
Cold	INFLUENZA	Seasonal transmission pattern
Dry	MENINGOCOCCAL MENINGITIS, COCCIDIOIDOMYCOSIS	Associated with arid conditions, dust storms
Wet	CRYPTOSPORIDISIS, RIFT VALLEY FEVER	Associated with flooding

Disease agents (viruses, bacteria, and other parasites) and their vectors (such as insects or rodents) each have particular environments that are optimal for growth, survival, transport, and dissemination. Factors such as precipitation, temperature, moisture, humidity, and ultraviolet radiation intensity are part of that environment. Each of these climatic factors can have markedly different impacts on the epidemiology of various infectious diseases.

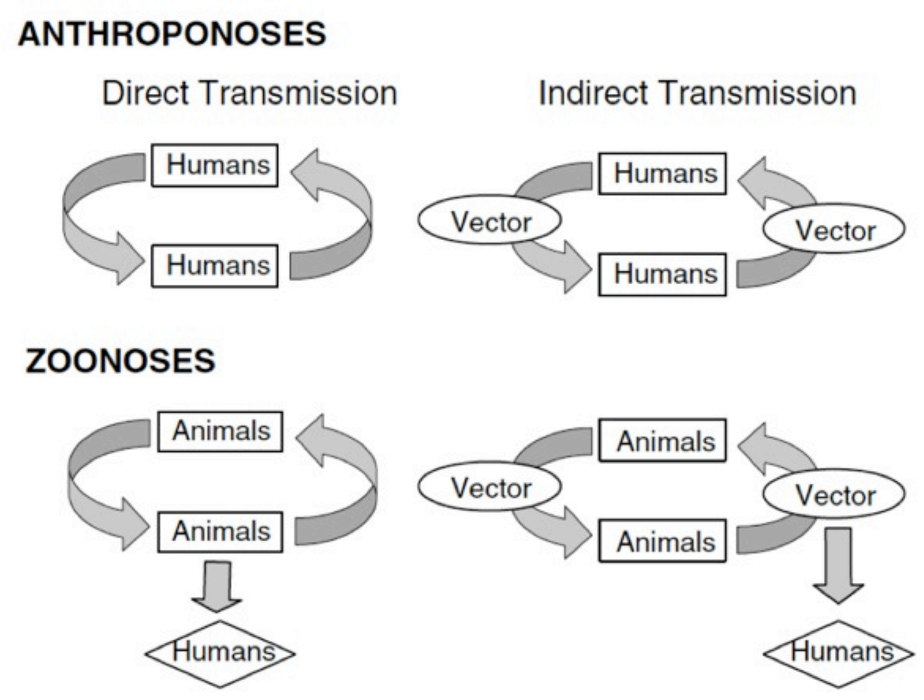

Illustration of the different types of infectious disease transmission cycles. The impacts of various climate factors on transmission will largely depend on the number of variables that characterize a pathogen's life cycle and the climate sensitivity of each of these variables. Directly transmitted anthroponoses, with the fewest variables and simple links, generally appear to be the least sensitive to climate influences. On the other hand, vector-borne zoonoses, with many environmentally sensitive links, may be highly influenced by climate. At the same time, this larger number of climate-sensitive links makes it more difficult to forecast how climatic changes will alter risk.

By carefully studying these associations and their underlying mechanisms, we hope to gain insights into the factors that drive the emergence and seasonal / interannual variations in contemporary epidemic diseases and, possibly, to understand the potential future disease impacts of long-term climate change.

Weather fluctuations and seasonal-to-interannual climate variability influence many infectious diseases. The characteristic geographic distributions and seasonal variations of many infectious diseases are prima facie evidence of linkages with weather and climate. Studies have shown that factors such as temperature, precipitation, and humidity affect the life cycle of many disease pathogens and vectors (both directly, and indirectly through ecological changes) and thus can potentially affect the timing and intensity of disease outbreaks.

Ecosystem instabilities brought about by climate change and concurrent stresses such as land use changes, species dislocation, and increasing global travel could potentially influence the genetics of pathogenic microbes through mutation and horizontal gene transfer, and could give rise to new interactions among hosts and disease agents. Such changes may foster the emergence of new infectious disease threats. However, disease incidence is also affected by factors such as sanitation and public health services, population density and demographics. The importance of climate relative to these other variables must be evaluated in the context of each situation.

References

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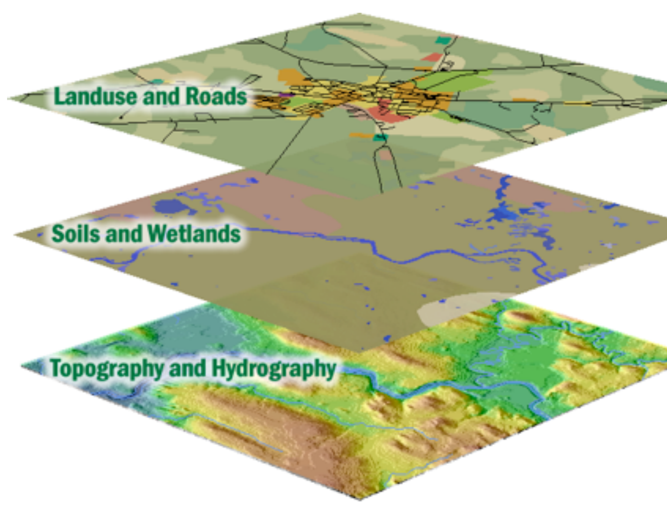
The potential for disease early warning system

Space technology applications to combat and even forecast the spread of disease are fundamental instruments in ensuring the health of current and future generations. **Satellite remote sensing**, **Global Navigation Satellite Systems (GNSS)**, and **Geographic Information Systems (GIS)** make it easier to integrate ecological, environmental and other data to predict the spread of diseases. Recent technological advances will aid efforts to improve modeling of infectious disease epidemiology. Rapid advances being made in several disparate scientific disciplines may spawn radically new techniques for modeling of infectious disease epidemiology. These include advances in sequencing of microbial genes, satellite-based remote sensing of ecological conditions, the development of Geographic Information System (GIS) analytical techniques, and increases in inexpensive computational power. Such technologies will make it possible to analyze the evolution and distribution of microbes and their relationship to different ecological niches, and may dramatically improve our abilities to quantify the disease impacts of climatic and ecological changes.

Remote sensing is the science of obtaining information about objects or areas from a distance, typically from aircraft or satellites. Remote sensors collect data by detecting the energy that is reflected from Earth. These sensors can be on satellites or mounted on aircraft. Remote sensors can be either passive or active. Passive sensors respond to external stimuli. They record radiation that is reflected from Earth's surface, usually from the sun. Because of this, passive sensors can only be used to collect data during daylight hours. In contrast, active sensors use internal stimuli to collect data about Earth. For example, a laser-beam remote sensing system projects a laser onto the surface of Earth and measures the time that it takes for the laser to reflect back to its sensor.

The term "GNSS" (Global Navigation Satellite System), is used to describe the collection of satellite positioning systems that are now operating or planned (GPS (United States), GLONASS (Russia), Galileo (European Union), Compass (China)).
GNSS satellite systems consist of three major components or "segments": space segments, control segment and user segment.
The space segment consists of GNSS satellites, orbiting about 20,000 km above the earth. Each satellite in a GNSS constellation broadcast a signal that identifies it and provides its time, orbit, and status.
The control segment comprises a ground-based network of master control stations, data uploading stations, and monitor stations.
The user segment consists of equipment that processes the received signals from the GNSS satellites and uses them to derive and apply location and time information.

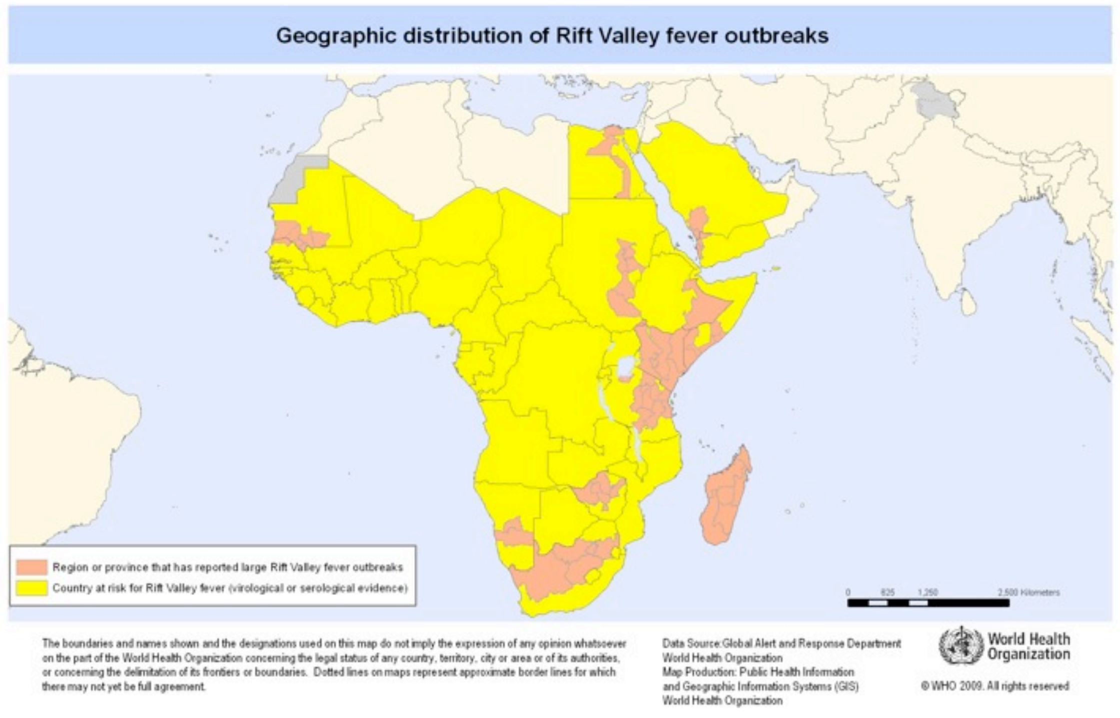


A geographic information system, or GIS, is a computerized data management system used to capture, store, manage, retrieve, analyze, and display spatial information. A GIS differs from other graphics systems in several respects. First, data are georeferenced to the coordinates of a particular projection system. This allows precise placement of features on the earth's surface and maintains the spatial relationships between mapped features. As a result, commonly referenced data can be overlaid to determine relationships between data elements. Second, GIS software use relational database management technologies to assign a series of attributes to each spatial feature. Common feature identification keys are used to link the spatial and attribute data between tables. Third, GIS provide the capability to combine various data into a composite data layer that may become a base layer in a database. GIS software generally allow for two types of data. Some use raster data (i.e., discrete cells in a rigid row by column format), such as satellite imagery or aerial photography,while others use vectors (points, lines and polygons) to represent features on the earth's surface.

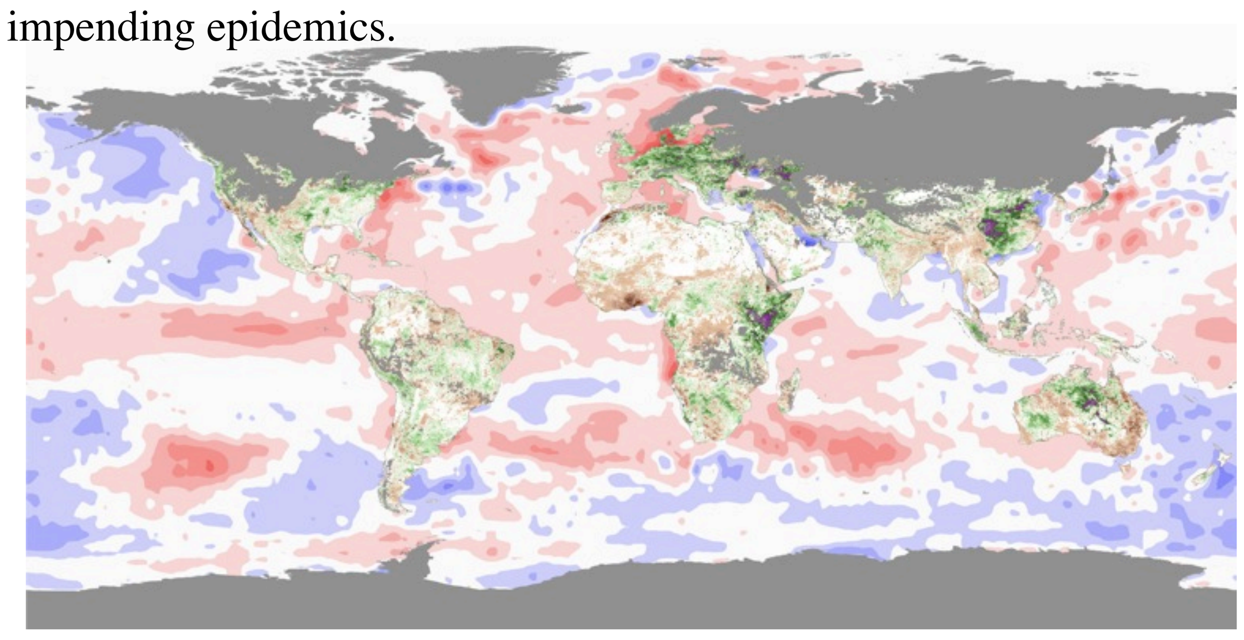
Satellite images and Geographical Information Systems (GIS) can provide public health officials with vital information needed to detect and manage certain disease outbreaks. In order to properly plan, manage and monitor any public health system, it is very important to have up to date, relevant information available to decision-makers at all levels throughout all regions of the world. By knowing the vegetation and geologic conditions necessary for the maintenance of specific pathogens in nature, one can use the landscape to identify the spatial and temporal distribution of disease risk. Satellite images can greatly enhance a GIS mapping project. Imagery is a powerful visual aid and serves as a source of derivative information such as planimetrics and classification schemes to derive such information as land cover and change detection or vegetation classification. Field observations and vector data retrieved on environmental conditions, including vegetation, water (hydrology), and topography, can be combined in a GIS mapping environment to direct interpretation of remote sensed data and facilitate characterization of the landscape in terms of vector and pathogen prevalence.

A case study: Rift Valley fever

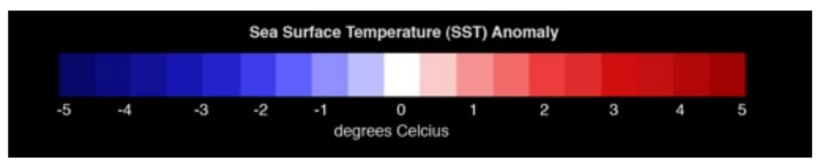
Rift Valley fever (RVF) is a viral zoonosis that was first identified in Kenya in 1931. This mosquito-borne disease primarily affects animals but that also has the capacity to infect humans. The vast majority of human infections result from direct or indirect contact with the blood or organs of infected animals. Such contact may occur during the care or slaughtering of infected animals or possibly from the ingestion of raw milk. Human infection can also result from the bites of infected mosquitoes.



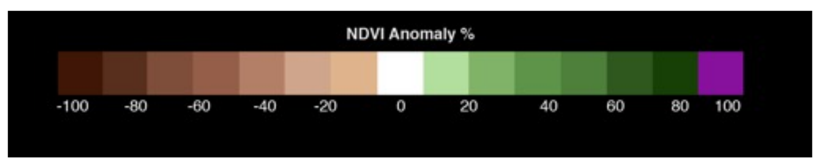
RVF outbreaks in East Africa are closely associated with periods of heavy rainfall that occurs during the warm phase of the El Niñø Southern Oscillation (ENSO) phenomenon. These findings have enabled the successful development of forecasting models and early warning systems for RVF using satellite images and weather/climate forecasting data enabling authorities to implement measures to avert impending epidemics.



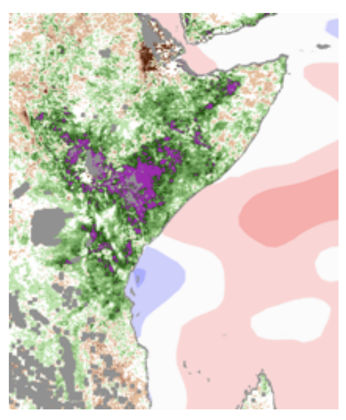
This map shows combined anomalies in Sea-Surface Temperatures(SST)(oceans) and Normalized Difference Vegetation Index (NDVI) (land), observed globally for January 2007. The unusually high Sea Surface Temperatures (red) sustained in the western equatorial Indian Ocean and the central and eastern equatorial Pacific Ocean since the fall of 2006 caused an anomalous growth in vegetation (green-purple), in Eastern Africa due to persistent and heavy rainfall. Above normal rainfall combined with growth in vegetation created ideal ecological conditions for the emergence of mosquitoes that spread Rift Valley fever.



SST data are a blend of direct observations from ships, buoys, satellite imagery also from National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) instruments, and SSTs simulated by sea-ice cover. The monthly optimum interpolated fields were derived by a linear interpolation of the weekly fields to daily fields, and then averaging daily values over a month.



NDVI is an index that quantifies the photosynthetic capacity of vegetation. It is derived from visible and near-infrared reflectance measurements made by Advanced Very High Resolution Radiometer (AVHRR) sensors onboard NOAA's polar orbiting satellites (in this case NOAA-17). Taken as time series measurements, NDVI indicates the response of vegetation to seasonal and interannual variations in climate.



Close view of East Africa region with SST and NDVI anomaly data observed in January 2007.

Conclusion

How vulnerable are we to disease epidemics ?
Without question, future mystery illnesses will emerge. The questions will be the same — what is causing the illness, where did it come from, can it be contained, who is at greater risk?
We really are all connected by just an airplane flight. It only takes one person at the wrong place, at the wrong time, for an explosive outbreak to take place.
We have emerging infections - and weather fluctuations and seasonal-to-interannual climate variability influence many infectious diseases - , drug-resistant microbes, globalization of travel, and increasing ease of creating threats in the lab.
Without a doubt, we are better prepared today than we have ever been, thanks to better coordination globally and the molecular innovations. Earth-observing satellites provide a transnational picture of vector-borne diseases - irrespective of national frontiers - and space-based data help scientists to predict high-risk areas before outbreaks occur, and new satellite platforms result in a better idea of risk factors and allow experts to make more informed decisions. The cost in lives and economic upheaval from future mystery illnesses will depend in part on how quickly we can detect the threat and answer the questions of life and death.