GEO Task US-09-01a: Critical Earth Observations Priorities

Health Societal Benefit Area: Infectious Diseases

GROUP ON EARTH OBSERVATIONS

User Interface Committee

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2010

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Acknowledgment

This study and report were funded by the U.S. Environmental Protection Agency (EPA) through Eastern Research Group, Inc. (ERG), as part of the Group on Earth Observations (GEO) project US-09-01a, which was managed by Lawrence Friedl of NASA on behalf of GEO's User Interface Committee. Jan Connery (ERG) provided overall coordination between the project team, EPA, and other research groups within the larger context of this project.

Summary

The goal of the Group on Earth Observations (GEO) Task US-09-01a is to identify the Earth observations (EO) that are critical for various societal benefit areas (SBAs). This analysis focuses specifically on the identification of observations required by users in the Health SBA- Infectious Diseases Sub-Area, more specifically vector-borne and non-vector-borne diseases that are influenced by climate and environmental factors. An *ad hoc* Advisory Group of 19 members from around the world was assembled to help identify documents; assess methodologies and analytic techniques; assess prioritization schemes; and review the results presented in the preliminary and final reports.

Documents potentially containing information related to observation requirements were identified through literature and Internet searches and through Advisory Group recommendations. After evaluating all documents for their applicability to this task, 823 were found to provide relevant information that could be used in the priority setting analysis. The relevant documents were analyzed within an Access database created for this project. The database file (Env-Health.mdb) is accessible via the web link: http://iri.columbia.edu/~pceccato/GEO-Human-Health-SBA-Access-database/.

Observation requirements were extracted from the documents for each of the two subareas individually. To provide a more complete picture of which observations were indicated as priority by the documents, the observations were grouped in four categories (*i.e.,* climate, environment, human dimension, vector ecology).

Although all the diseases are important since they affect human population and therefore any EO parameter used should be treated as equal, it was decided to prioritize the EO parameters according to the burden of the disease. The overall burden of disease was assessed using the disability-adjusted life year (DALY), a time-based measure that combines years of life lost due to premature mortality and years of life lost due to time lived in states of less than full health. The EO parameters will be ranked based on the DALY values using a cumulative impact. Four lists of EO priorities then were created for each of the four categories.

These priority lists, along with the specific physical requirements for the observations, will ultimately be incorporated into a broad cross-SBA analysis to be performed by GEO to identify critical Earth observations across all nine SBAs.

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1 Introduction

This report communicates Earth observation priorities for the Health SBA-Infectious Diseases Sub-Area based on an analysis of 823 publicly available documents. Documents analyzed included peer-reviewed articles, documents, and reports produced by member countries of the Group on Earth Observations (GEO) and its participating organizations, as well as organizations not included in GEO.

1.1 Group on Earth Observations

The Group on Earth Observations[1] is an intergovernmental organization working to improve the availability, access, and use of Earth observations to benefit society. GEO is coordinating efforts to build a Global Earth Observation System of Systems (GEOSS)[2]. GEOSS builds on national, regional, and international observation systems to provide coordinated Earth observations from thousands of ground, airborne, and space-based instruments.

GEO is focused on enhancing the development and use of Earth observations in nine Societal Benefit Areas (SBA):

Agriculture	Biodiversity	Climate
Disasters	Ecosystems	Energy
Health	Water	Weather

1.2 GEO Task US-09-01a

The objective of GEO Task US-09-01a is to establish and conduct a process to identify the critical Earth observation priorities within each Societal Benefit Area (SBA) and those common to the nine SBAs. Many countries and organizations have written reports, held workshops, sponsored projects, conducted surveys, and produced documents that specify Earth observation needs. Researchers and practitioners have also identified and recommended key Earth observation needs in publications and peer-reviewed literature. Task US-09-01a focuses on compiling information on observation parameters from a representative sampling of these existing materials and analyzing the materials to determine the priority observations.

[1] GEO Web site: *http://www.earthobservations.org*
[2] GEO 10-Year Implementation Plan: *http://www.earthobservations.org/documents.shtml*

This task considers all types of Earth observations, including ground, in situ, airborne, and space-based observations. The task considers direct measurements and derived parameters as well as model products. This task seeks to identify Earth observation needs across a full spectrum of user types and communities in each SBA, including observation needs from all geographic regions with significant representation from developing countries.

GEO will use the Earth observation priorities defined in this task to determine, prioritize, and communicate gaps in current and future Earth observations. GEO Member Countries and Participating Organizations can use the results to determine priority investment opportunities for Earth observations.

1.3 Purpose of Report

The primary purpose of this report is to communicate the critical Earth observation priorities for the Health SBA- Infectious Diseases Sub-Area. The intent of the report is to describe the overall process and specific methodologies used to identify documents, analyze the relevant ones, and determine a set of Earth observation parameters and characteristics. The report describes the prioritization methodologies used to determine the priority Earth observations for this SBA. The report also provides information on key challenges faced, feedback on the process, and recommendations for process improvements.

The primary audience for this report is the GEO User Interface Committee (UIC), which is managing Task US-09-01a for GEO. The GEO UIC will use the results communicated in this report in combination with reports from the other eight SBAs. The GEO UIC will perform a meta-analysis across all nine SBA reports to identify critical Earth observation priorities common to many of the SBAs. Based on the nine SBA reports, the GEO UIC will produce an overall Task US-09-01a report, including the common observations and recommendations for GEO processes to determine Earth observation priorities in the future.

The report's authors anticipate that the GEO secretariat, committees, member countries, participating organizations, observers, communities of practice, and the communities associated with the Health SBA- Infectious Diseases Sub-Area are additional audiences for this report.

1.4 Scope of Report

This report addresses the Earth observation priorities for the Health SBA- Infectious Diseases Sub-Area. In particular, this report addresses the subareas of ***Vector-Borne Infectious Diseases and Non-Vector-Borne Infectious Diseases*** within the Health SBA- Infectious Diseases Sub-Area (see Section 3 for more details).

The report provides some background and contextual information about the Health SBA- Infectious Diseases Sub-Area. However, this report is not intended as a handbook or primer on the Health SBA- Infectious Diseases Sub-Area, and a complete description of the Health SBA- Infectious Diseases Sub-Area is beyond the scope of this report. Please consult the GEO website for more information about the Health SBA- Infectious Diseases Sub-Area.

The report focuses on the Earth observations within the Health SBA- Infectious Diseases Sub-Area, independent of any specific technology or collection method. Thus, the report addresses the "demand" side of observation needs and priorities. The report does not address the specific source of the observations or the sensor technology involved with producing the observations. Similarly, any discussions of visualization tools, decision support tools, or system processing characteristics (e.g., data format, data outlet) associated with the direct use of the observations are beyond the scope of this report.

In this report, the term Earth observation refers to parameters and variables (*e.g.*, physical, geophysical, chemical, biological) sensed or measured, derived parameters and products, and related parameters from model outputs. The term Earth observation priorities refers to the parameters deemed of higher significance than others for the given SBA, as determined by the methodologies described within. The report uses the terms "user needs" and "user requirements" interchangeably to refer to Earth observations that are articulated and desired by the groups and users in the cited documents. The term "requirements" is used generally in the report to reflect users' wants and needs; its use in this report does not imply technical, engineering specifications.

Section 2 of this report discusses the overall approach and methodologies used in the analysis. Section 3 describes the Health SBA- Infectious Diseases Sub-Area and the specific subareas that were part of the analysis. Section 4 communicates the specific Earth observations for each Human Health Infectious Diseases subarea, and Section 5 presents the priority observations across the Health SBA- Infectious Diseases Sub-Area. Sections 6 and 7 present additional findings from the analysis of the documents and any resulting recommendations (Gap Analysis). The appendices include the list of acronyms, the classification of pathogen agents, the documents cited, and the documents consulted.

2 Methodology

This section documents the general process followed and specific methodologies used to identify documents, analyze them, determine Earth observation parameters and characteristics, and establish a set of priority Earth observations for this SBA.

2.1 Task Process

The GEO UIC established a general process for each of the SBAs to follow in order to ensure some consistency across the SBAs. This general process for each SBA involves nine steps, as summarized in the following list:

Step 1: Identify Analyst and Advisory Group for the SBA
Step 2: Determine the scope of topics within the SBA
Step 3: Identify documents regarding observation priorities for the SBA
Step 4: Develop analytic methods and priority-setting criteria
Step 5: Review and analyze documents for priority Earth observations needs
Step 6: Combine the information and develop a preliminary report
Step 7: Gather feedback on the preliminary report
Step 8: Perform any additional analysis
Step 9: Complete the report on Earth observations for the SBA

A detailed description of the general US-09-01a process is available at the Task website (*http://sbageotask.larc.nasa.gov*) or the GEO website. Some steps in the process occurred simultaneously or iteratively, such as identification (Step 3) and review of documents (Step 5).

2.2 Analyst and Advisory Group

The Health SBA- Infectious Diseases Sub-Area had an “Analyst” and an “Advisory Group” to conduct the process of identifying documents, analyzing them, and prioritizing the Earth observations. The Analyst served as the main coordinator to manage activities.

2.2.1 Analyst

For the Health SBA- Infectious Diseases Sub-Area, the Analyst was Pietro CECCATO. Pietro trained originally as an agronomist and soil science scientist. He obtained a Master’s degree in Environmental Management using decision-support systems and worked as a research scientist at the Natural Resources Institute in the United Kingdom. He developed remote sensing products to monitor active fires and vegetation status for the purpose of assessing the risk of

fire occurrence. He worked at the European Commission Joint Research Centre (Ispra, Italy) on the use of remote sensing to monitor vegetation status and used this work to obtain his Ph.D. in Remote Sensing (2001, University of Greenwich, UK). Pietro then joined the UN Food and Agriculture Organization (Rome, Italy) to develop an early warning system for desert locust monitoring. He has developed remote sensing products and Geographical Information Systems to be used operationally by the ministries of agriculture in 21 countries in Africa and Asia.

Pietro joined the International Research Institute for Climate and Society in 2004. His current research activities include the development and integration of environmental remote sensing products into early warning systems for human health.

The Health SBA- Infectious Diseases Sub-Area Analyst served under an Eastern Research Group, Inc. (ERG) contract funded by U.S. Environment Protection Agency (EPA).

2.2.2 Advisory Group

The Analyst identified the Advisory Group (AG) members through personal contacts and professional associations. The Analyst attempted to recruit Advisory Group members from all geographic regions and from multiple developing countries. The Analyst contacted 20 people to participate in the Advisory Group. Nineteen expressed interest; and one was unable to participate but provided suggestions for possible replacement Advisory Group members. Overall, the Advisory Group includes members from eight countries and five continents, including four developing countries.Table 1 lists the AG members.

Table 1: Advisory Group Members

GEO Task US-09-01a: Advisory Group for Human Health Infectious Diseases				
Name	**GEO Country or Organization**	**Affiliation**	**Geographic Region**	**Area of Expertise/ Specialty**
Ulisses E.C. CONFALONIERI	Brazil	FIOCRUZ	Americas	Remote sensing, Public Health, Infectious Disease Ecology
Stephen J. CONNOR	USA	IRI - WHO - PAHO	Africa, Americas, Asia	Remote sensing, Environment, Infectious Diseases
Pat DALE	Australia	Griffith University	Australia	Remote sensing, Environment, Infectious Diseases
Joaquim DASILVA	Zimbabwe	WHO - AFRO	Africa	Medicine, Public Health, Disease Control Systems

GEO Task US-09-01a: Advisory Group for Human Health Infectious Diseases				
Name	**GEO Country or Organization**	**Affiliation**	**Geographic Region**	**Area of Expertise/ Specialty**
Ruth DEFRIES	USA	Columbia University	Africa, Americas, Asia	Remote Sensing, Land Cover Change
Gregory GLASS	USA	JHBSPH	Americas	Modeling Infectious Disease Risk
John HAYNES	USA	NASA	Americas	Meteorology, Remote Sensing
Darby JACK	USA	MSPH	Africa, Americas	Development, Economics, Environmental Health
Isabelle JEANNE	France	Consultant	Africa	GIS, Remote Sensing and Spatial Analysis for Health
Erick KHAMALA	Kenya	RCMRD	Africa	Remote Sensing
Patrick KINNEY	USA	MSPH	Africa, Americas	Public Health
Uriel KITRON	USA	Emory University	Africa, Americas	Infectious Diseases Ecology, GIS, Remote Sensing
Murielle LAFAYE	France	CNES	Europe, Africa, Asia, South America	Health Applications, Remote Sensing, Telecommunication
Forrest MELTON	USA	CSUMB	Americas	Remote Sensing, Ecosystem Modeling, Decision Support System
Jacques André NDIONE	Senegal	CSE	Africa	Climatologist Working on Environment Changes and Health Issues
Masami ONODA	Switzerland	GEO Secretariat	International	Environmental Policy, Satellite Program Management and Data Policy
David ROGERS	Switzerland	HCF	Africa, Americas	In-Situ Observation and Utilization of EO Information
Leonid ROYTMAN	USA	NOAA-CREST	Asia	Remote Sensing for Infectious Diseases
Juli TRTANJ	USA	NOAA	Americas	Human Health, Oceans

The primary role of the AG was to assist in identifying documents; assess methodologies and analytic techniques; assess prioritization schemes; review findings; and review reports.

The primary contact with the AG was through emails, teleconferences, and a workshop (July 10' 2009). Over the course of the study, the Analyst conducted 14 individual meetings with Advisory Group members, 12 teleconferences, and

sent/received 321 email communications. A workshop was held in Geneva on July 10, 2009. Nine AG members and three observers were present at the workshop. A summary of the workshop and the PPT presentations from the participants are available on the web page: http://iri.columbia.edu/~pceccato/AG-Workshop-July-10-2009/.

2.3 Methodology

This section provides a general description of the processes, analytic methods, and approaches the Analyst/AG used to identify documents, analyze them, and establish a set of priority Earth observations.

2.3.1 Documents

The analysis used literature reviews, Internet searches, and Advisory Group recommendations to identify documents that included references to Earth observation requirements. A wide range of documents were examined including:

- Peer-reviewed documents selected for the period 2000-2009 through:
    - ISI Web of Knowledge
    - Google Scholar

    Using multiple combinations of the following keywords:
    "Infectious diseases – specific name of disease – environment – climate – remote sensing – satellite"
    - CHAART Remote Sensing/GIS Human Health web site: http://geo.arc.nasa.gov/sge/health/rsgisbib.html

- Reports obtained from:
    - International Federation of Red Cross and Red Crescent Societies (IFRC)
    - National Center for Atmospheric Research (NCAR)
    - UN Development Programme (UNDP)
    - UN Food and Agriculture Organization (FAO)
    - UN World Health Organization (WHO)
    - UN World Meteorological Organization (WMO)
    - US National Aeronautics and Space Administration (NASA)
    - US National Oceanic and Atmospheric Administration (NOAA)
    - US The National Academies

- Other documents obtained through:
    - Web search for English, Spanish, Portuguese, French, and Chinese literature using the following key words:
        - ***For English and Chinese***: "Infectious diseases – specific name of disease – environment – climate – remote sensing – satellite"
        - ***For Spanish***: "Metereologia enfermedades infecciosas – Enfermedad sensores remotos – Geografia medica – Enfermedades precipitación mensual – Indices climaticos – Enfermedad epidemiologia satelital – Enfermedad ecoepidemiologia sensores remotos – Tendencia precipitación pluviosidad – Enfermedad correlacion pluviometrica – Enfermedad distribución clima – Enfermedad calentamiento global – Salud cambio climatico – Salud humana variabilidad climatica – Enfermedad"
        - ***For Portuguese***: "Mudancas climaticas saude – Estudo epidemiológico mudancas Climaticas – Incidência doenca variáveis climáticas – *Riscos ambientais saude humana – Ecossistema de saude*"
        - ***For French***: "Epidémiologie – Télédétection – Climat – Santé publique"
    - Requests made to universities and governmental agencies including:
        - Prof. Vladimir Badenko, SPb State Polytechnical University 195251, Saint-Petersburg, Russia and Emercom of Russia, Federal Center of Science and High Technologies, Civil Defense and Disaster Management
        - Antioquia University, Colombia (email: coocurpme_fcbog@unal.edu.co)
        - Universidad Nacional de Colombia (email: coocurpme_fcbog@unal.edu.co)
        - Ministry of Health and Infectious Diseases Control Bureau in China (emails: service@newhealth.com.cn, manage@moh.gov.cn)

2.3.2 Analytic Methods

Each document was evaluated for its usefulness in describing specific observation requirements. Relevant information was extracted and inventoried into a single Access database created for this project (see Figure 1).

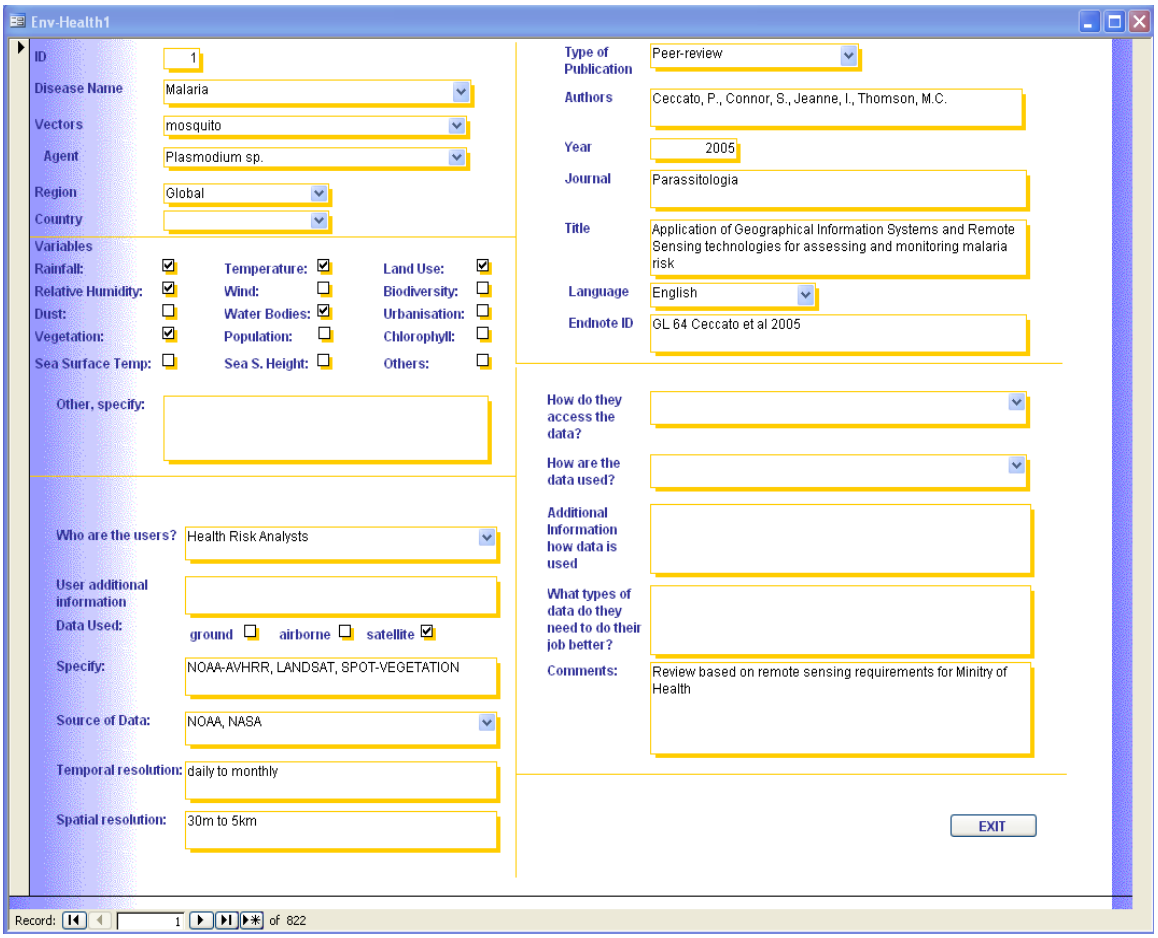

Figure 1: Classification of Information Collected from the Analyzed Documents

The database collected information and sources as follows:

<u>Information on the diseases</u>:

- Disease name
- Vector
- Agent
- Region
- Country

<u>EO Variables</u>:

- Rainfall
- Temperature
- Land use/land cover
- Relative humidity
- Wind

- Biodiversity
- Dust
- Water bodies
- Urbanization
- Vegetation
- Population
- Chlorophyll
- Sea surface temperature
- Sea surface height
- Other EO variables

Users and Types of Data:

- Who are the users?
- Data used
- Source of data
- Temporal resolution
- Spatial resolution

Bibliography:

- Type of publication
- Authors
- Year
- Journal
- Title
- Language
- ID code to link to the corresponding PDF documents

Additional Information on Data:

- How do the users access the data?
- How are the data used?
- Additional information regarding how data are used
- What type of data do they need to do their job better?
- Comments

The database constructed allowed us to easily extract any relevant information that is shown in the following analysis sections.

The Access database is made available for consultation and analysis through the web site: http://iri.columbia.edu/~pceccato/GEO-Human-Health-SBA-Access-database/.

2.3.3 Prioritization Methods

During the workshop in Geneva, we discussed different approaches to prioritize the EO parameters. It was agreed that prioritizing the EO parameters based on statistical analysis of either the number of publications, or the number of times a parameter was cited, could be misleading. Instead, although all the diseases are important since they affect human population and therefore any EO parameter used should be treated as equal, it was decided to prioritize the EO parameters according to the burden of the disease. The Disease Burden list produced by UN WHO (2005) was used to prioritize the EO parameters. In the UN WHO (2005) document, the overall burden of disease was assessed using the disability-adjusted life year (DALY), a time-based measure that combines years of life lost due to premature mortality and years of life lost due to time lived in states of less than full health (Table 2)[3].

Several diseases of interest did not have a quantified global burden value on this list. For the purposes of this study, we assumed a DALY value of at least one. This value can easily be adjusted if new information is received.

Table 2: Disease Burden Classification (WHO 2005)

Diseases	Global Burden (1000 DALYs)
HIV AIDS	95 805
Influenza (Acute respiratory virus)	94 603
Diarrheal diseases (incl. cholera)	61 966
Malaria	46 486
Meningococcal meningitis	6 192
Lymphatic filariasis	5 777
Intestinal nematodes (incl. Ascariasis, Hookworm)	2 951
Trachoma	2 329
Leishmaniasis	2 090

[3] Although the approach to classify EO based on DALY has some limitations (*e.g.,* difficulty in quantifying the importance of emerging diseases, some diseases are not properly reported), we found that DALY is currently the best indicator able to give an assessment of disease impacts on health.

Diseases	Global Burden (1000 DALYs)
Schistosomiasis	1 702
Africa Trypanosomiasis	1 525
Japanese encephalitis	709
Chagas disease (American trypanosomiasis)	667
Dengue	616
Onchocerciasis	484
St Louis encephalitis	Unquantified: 1
Rift Valley fever	Unquantified: 1
West Nile fever	Unquantified: 1
Ross River virus	Unquantified: 1
Murray Valley fever	Unquantified: 1
Lyme disease	Unquantified: 1
Yellow fever	Unquantified: 1
Ebola	Unquantified: 1
Plague	Unquantified: 1
Salmonella	Unquantified: 1
Hemorrhagic fever	Unquantified: 1
Hemorrhagic fever with renal syndrome	Unquantified: 1
Hantavirus	Unquantified: 1
Kunjin virus	Unquantified: 1
Brucella	Unquantified: 1
Toxoplasmosis	Unquantified: 1
Leptospirosis	Unquantified: 1

Diseases	Global Burden (1000 DALYs)
Chickungunya	Unquantified: 1
Barmah forest virus	Unquantified: 1
Blue tongue	Unquantified: 1
Crimean-Congo hemorrhagic fever	Unquantified: 1
Fasciolosis	Unquantified: 1
Amoebiasis	Unquantified: 1
Shigellosis	Unquantified: 1
Guinea worm	Unquantified: 1
Rotavirus	Unquantified: 1
Typhoid	Unquantified: 1
African eye worm	Unquantified: 1

The EO parameters will be ranked based on the DALY values using a cumulative impact computed following equation 1:

$$Cumulative\_Impact = \sum_{i=1}^{n} DALY_i(x_i) \quad \text{.....(1)}$$

Where n = number of diseases; x_i = EO parameter for disease i; and $DALY_i$ = DALY value for disease i (see Section 5 for results).

3 Health SBA- Infectious Diseases Sub-Area

3.1 Health SBA- Infectious Diseases Sub-Area Description

Many factors impacting human health can potentially be managed and/or monitored using Earth Observation methodologies. These factors include: air quality; aeroallergens; airborne, marine and water pollution; stratospheric ozone depletion; persistent organic pollutants; environmental typology; population; vector and host ecology; weather; and climate. This analysis specifically focuses on **infectious diseases** resulting from the presence of pathogenic microbial

agents, including viruses, bacteria, protozoa and multicellular parasites. These pathogens are able to cause disease in animals and/or humans. Table 3 lists the pathogenic agents.

Table 3: Pathogenic Agent Definitions

Pathogenic agent	Definition
Virus	A virus is an organism without nucleus with only one sort of nucleic acid: Desoxyribonucleic Acid (DNA) or Ribonucleic Acid (RNA).
Bacteria	A bacterium is a unicellular organism, with a nucleus not clearly delimited (*i.e.,* it is a prokaryote) with only one chromosome. Depending on its shape, a bacterium may be a bacillus (rods form), a coccus (spheric form) or a spirochete (spiral form).
Parasite	A parasite is a unicellular or multicellular organism that has a nucleus clearly limited (*i.e.,* it is a eukaryote). A parasite is defined by its life cycle. It is an organism that lives at the expense of other organism(s).

Infectious diseases refer to contagious (*i.e.,* directly transmitted within a same species) and transmissible diseases. Transmissible diseases require an external factor for one or more step of maturation of the pathogen agent, from a simple step outside the body to a necessary intervention of at least one host of another species in the transmission cycle.

In this analysis, we decided to classify infectious diseases into two broad categories:

- Vector-Borne Diseases transmitted by an arthropod (vector). This includes diseases transmitted by insects (*e.g.,* mosquitoes, flies, fleas), crustaceans (*e.g.,* copepods), or arachnids (*e.g.,* ticks and mites)

- Non-Vector-Borne Diseases transmitted by contact with zoonotic hosts (*e.g.,* snails, rodents, bats) or nonzoonotic reservoirs (*e.g*., soil, water, food, body fluids, air)

The diseases selected in these two categories are all impacted by climate or ecological factors and contain some, but not all, emerging and reemerging infectious diseases defined as “infections that have newly appeared in a population or have existed previously but are rapidly increasing in incidence or geographic range” (Morens *et al.*, 2004; Morse, 1995).

3.2 Subareas

3.2.1 Vector-Borne Diseases

Table 4 summarizes the vector-borne diseases studied.

Table 4: Infectious Diseases, Vector-borne

Disease	Pathogen	Vector
Dengue[1]	Virus	Mosquito (Aedes sp.)
Rift valley fever[1]	Virus	Mosquito (Aedes and Culex sp)
Yellow fever[1]	Virus	Mosquito (Aedes sp, Haemagogus sp., Sabethes sp.)
St. Louis encephalitis[1]	Virus	Mosquito (Culex sp.)
Japanese encephalitis[1]	Virus	Mosquito (Culex sp.)
Murray valley encephalitis[1] (also known as Australian encephalitis)	Virus	Mosquito (Culex sp) – Intermediate host: Bird
Ross river virus	Virus	Mosquito (Aedes sp., Culex sp.) – Intermediate hosts: Kangaroos, bats, and possums
Kunjin virus	Virus	Mosquito (Culex sp.)
West Nile fever[1]	Virus	Mosquito (Culex sp.) – Intermediate hosts: birds
Chikungunya[1]	Virus	Mosquito (Aedes sp.)
Barmah Forest virus	Virus	Mosquito (Aedes sp., Culex sp.) – Intermediate hosts: Kangaroos, bats, and possums
Blue tongue	Virus	Midge (Culicoides sp.)
Crimean-congo hemorrhagic fever	Virus	Tick
Lyme disease[1]	Bacteria	Ticks – Intermediate hosts: rodents, deer
Plague	Bacteria	Fleas – Intermediate hosts: rodents
Trachoma	Bacteria	Fly[2]
Malaria[1]	Parasite	Mosquito (Anopheles sp.)
African Trypanosomiasis[1]	Parasite	Tsetse fly
American Trypanosomiasis (Chagas)[1]	Parasite	Triatominae
Leishmaniasis[1]	Parasite	Sand fly
Onchocerciasis	Parasite	Black fly

Disease	Pathogen	Vector
African eye worm	Parasite	Deer Fly
Lymphatic filariasis	Parasite	Mosquito (Anopheles, Aedes, Culex spp.)
Guinea worm	Parasite	Copepod[3]

[1]Denotes emerging or reemerging diseases as defined by Jones *et al.*, (2008). More information on virus, bacteria and parasite is provided in Appendix B.
[2]Mechanical not a biological vector.
[3]Arthropod, but not vector transmitted.

3.2.2 Non-Vector-Borne Diseases

Table 5 summarizes the non-vector-borne diseases studied.

Table 5: Infectious Diseases, Non-Vector-Borne

Disease	Pathogen	Vector
Hemorrhagic fever with renal syndrome	Virus	Rodent
Acute respiratory virus (Avian flu)*	Virus	Bird
Influenza*	Virus	Human contact
Ebola hemorrhagic fever*	Virus	Bats, Nonhuman primates, Human contact
HIV-AIDS*	Virus	Human contact
Rotavirus	Virus	Fecal-oral route
Hantavirus	Virus	Rodent
Brucella*	Bacteria	Infected animals
Shigellosis	Bacteria	Water-fecal route
Leptospirosis*	Bacteria	Mammals (urine)
Meningococcal meningitis	Bacteria	Saliva droplets (not fully documented)
Diarrheal diseases *	Bacteria	Fecal, oral, water, feces
Cholera*	Bacteria	Copepod
Salmonella	Bacteria	Water, food
Typhoid	Bacteria	Fecal-oral route
Amoebiasis	Parasite	Fecal-oral route
Ascariasis	Parasite	Fecal-oral-soil-vegetation route
Hookworm	Parasite	Soil route
Fasciolosis	Parasite	Snail
Toxoplasmosis*	Parasite	Cat
Schistosomiasis	Parasite	Snail

* Denotes emerging or reemerging diseases as defined by Jones *et al.*, (2008). More information on virus, bacteria and parasite is provided in Appendix B.

3.3 Documents

The documents were analyzed within an Access database created especifically for this study. The Access database is available through the web site: http://iri.columbia.edu/~pceccato/GEO-Human-Health-SBA-Access-database/.

Table 6 summarizes the number of documents collected by geographic region and by subarea.

Table 6: Document Sources for Human Health Infectious Diseases

Geographic Region	Number of Documents	Subarea	Number of Documents
International	194	Vector-borne diseases	556
Africa	131	Non-vector-borne diseases	267
Asia	198		
Europe	64		
North America	95		
Oceania/Australia	39		
Polar Regions	1		
South/Central America	101		

Table 7 summarizes the number of documents collected by diseases.

Table 7: **Number of Documents Collected by Diseases**

GEO Task US-09-01a: Document Sources for Human Health Infectious Diseases	
Subarea	**Number of Documents**
Vector-borne disease	
Multidiseases (related to Climate and Environment)	205 (English), 13 (Spanish), 3 (Portuguese), 9 (French)
Malaria	54 (English), 8 (Spanish), 1 (Portuguese), 14 (Chinese)
Trypanosomiasis (African and Chagas American)	19 (English), 2 (Spanish)
Leishmaniasis	10 (English), 2 (Spanish), 1 (Portuguese)
Onchocercasis	3 (English)
African eye worm	4 (English)

GEO Task US-09-01a: Document Sources for Human Health Infectious Diseases	
Subarea	**Number of Documents**
Lymphatic filariasis	4 (English)
Dengue	23 (English), 5 (Spanish), 5 (Portuguese), 12 (Chinese)
Rift valley fever	14 (English), 3 (French)
Yellow fever	14 (English)
St. Louis encephalitis	4 (English)
Japanese encephalitis	5 (English), 10 (Chinese)
Murray valley encephalitis	4 (English)
Ross river virus	24 (English)
Kunjin virus	1 (English)
West Nile fever	24 (English)
Lyme disease	15 (English)
Plague	7 (English), 1 (Portuguese), 1 (Chinese)
Chickungunya	4 (English)
Barmah forest virus	3 (English)
Blue tongue	19 (English), 1 (Spanish)
Crimean-congo hemorrhagic fever	2 (English)
Guinea worm	2 (English)
Trachoma	2 (English)
Non-vector-borne disease	
Hemorrhagic fever with renal syndrome	6 (English), 1 (Spanish), 7 (Chinese)
Hantavirus	23 (English), 3 (Spanish)
Brucella	1 (English)
Toxoplasmosis	4 (English)
Leptospirosis	6 (English), 1 (Portuguese)
Acute respiratory virus, SARS, and avian flu	25 (English), 7 (Spanish), 18 (Chinese)
Meningococcal meningitis	12 (English), 1(Chinese), 1 (French)
Diarrheal diseases	8 (English), 7 (Chinese)
Cholera	36 (English), 2 (Chinese), 1 (French)
Salmonella	5 (English), 6 (Chinese)
Influenza	13 (English), 2 (Chinese)
Ebola hemorrhagic fever	4 (English)
HIV-AIDS	5 (English)
Amoebiasis	1 (English)
Ascariasis	2 (English)
Hookworm	4 (English)
Shigellosis	4 (English)
Rotavirus	3 (English)
Typhoid	2 (English)
Fasciolosis	5 (English)
Schistosomiasis	24 (English), 32 (Chinese)

3.4 Users

In order to understand the critical Earth observation priorities for the Health SBA-Infectious Diseases Sub-Area, we identified the user communities requiring Earth Observations and classified their needs.

3.4.1 User Types

Through literature review and discussions with experts and Advisory Group members, we identified a "chain of users" starting from the research community and ending at the decision-makers with entities identified as boundary organizations providing an informational link between the two endpoints of the user chain.

Table 8 summarizes the users identified in this analysis.

Table 8: User Types for Human Health Infectious Diseases

User Type	Examples Found in the Literature Review and Suggested by AG Members
1. Research Communities	Epidemiologists, animal health scientists, biologists, climatologists, ecologists, entomologists, environmental scientists, epidemiologists, geographers, marine biologists, parasitologists, public health risk modelers, public health scientists, remote sensing specialists, veterinarians, zoologists, development researchers, social science and political science researchers, modelers
2. Boundary organizations	International agencies: UN WHO, PAHO, AFRO, UN WMO, UN FAO, IFRC, World Bank National Meteorological and Hydrological Services Spatial agencies: NASA (Applied Sciences Program), NASA (SERVIR), ESA (Epidemio program and RESPOND project), CNES (RedGems), CNES (Dept. Applications and Valorisation) Research and development centers: IRI (Columbia University), Instituts Pasteur, IRD, USAID (FEWS Net, ADDS for Malaria Early Warning System), Public Health Department Canada (Global Public Health Intelligence Unit), Jena Optronik, ISID (Pro-MED program), MARA, RBM, MARC (Australia), CIRAD, INRA, INSERM, AFFSET, AFFSA

User Type	Examples Found in the Literature Review and Suggested by AG Members
3. Decision-Makers	National and subnational public health agencies, policy makers, general public, NGOs and advocacy group

3.4.2 User Needs

Through the analysis of the user communities and the classification adopted in 3.4.1, we identified user needs by analyzing the decision-making processes in which they are involved. We decided to represent the interactions between the different communities via a "User Cycle" as illustrated in Figure 2.

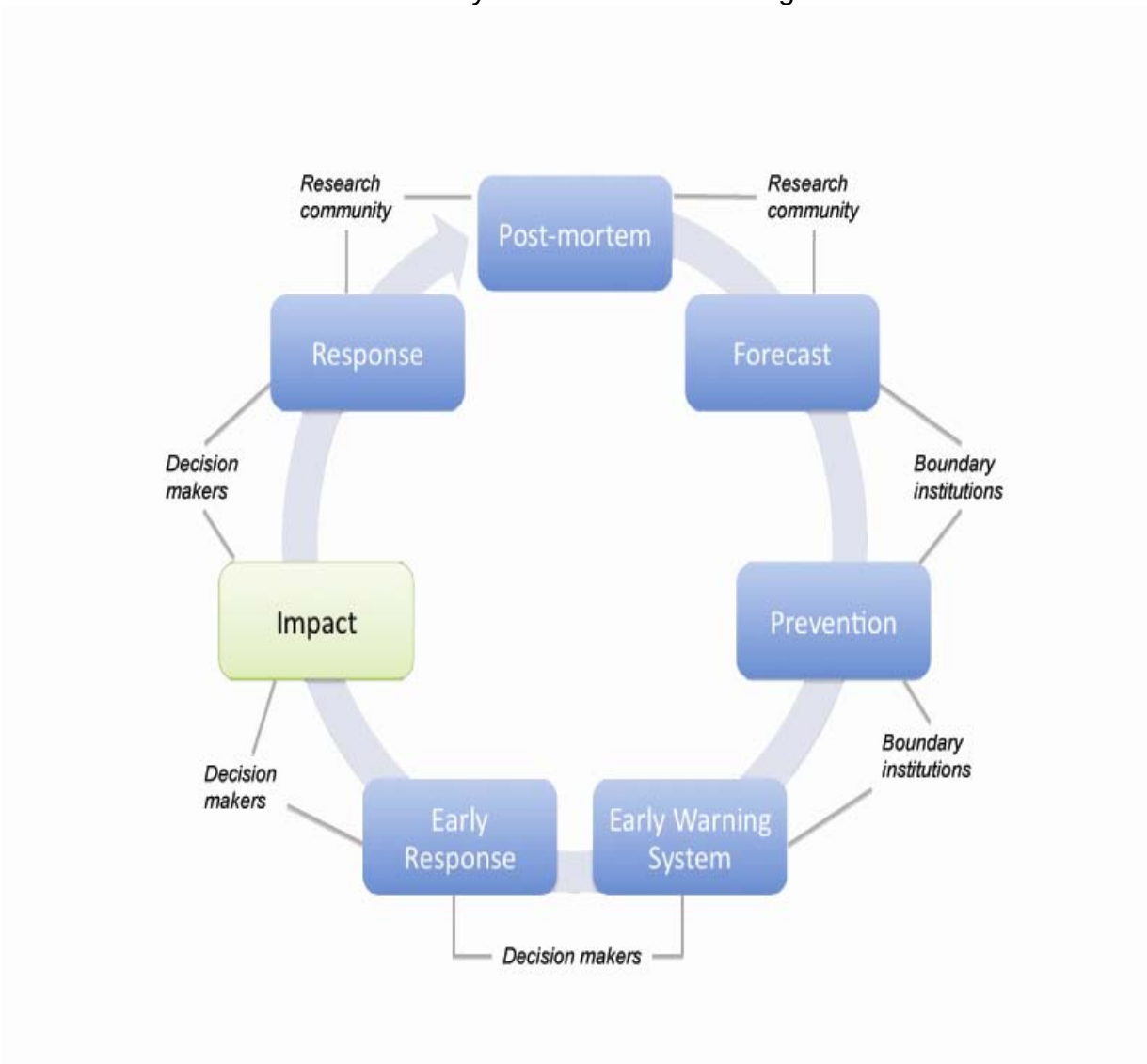

Figure 2: User Cycle Framework

Figure 2 shows the actions that are incorporated in disease control and prevention starting with ***Forecast*** activities, followed by ***Prevention***, ***Early Warning***, ***Early Response***, ***Response*** after the occurrence of the disease (***Impact***) and finally ***Post-Mortem Evaluation***. The process is represented as a loop in which feedback mechanisms should be incorporated in order to improve the cycle with each evolution and assessment.

Within this cycle, the three communities interact as follows:

- The research communities mainly use **data**: that is, raw EO data derived from in-situ measurements or remote-sensing techniques (*e.g.,* rain gauge measurements or single reflectance channels) or derived **information** (*e.g.,* NDVI, CMAP, CMORPH) to analyze the relationship between epidemiological data (human and animal) and climate/environmental factors. The research communities include different experts (researchers, modelers and forecasters) who use data and models to produce **information** and **products**.

- The boundary institutions use the **information** (*e.g.,* vegetation indices, rainfall estimates) produced by the research communities and translate it into **products**. In the literature review, we have identified a series of boundary institutions which develop **products** (*e.g.,* rainfall anomalies products; tools to analyze time-series of rainfall anomalies derived from satellite images, rainfall forecast derived from GCM models).

- The decision-makers then use the **products** which are directly or indirectly related to Earth observations (*e.g.,* rainfall forecast products derived from models which integrate EO, rainfall anomalies and temperature anomalies).

For each of these three categories of data, information and products, we investigated the EO parameters required to understand the relationship between the disease (pathogen), the vector and the environment/climate factors. To facilitate the analysis of the different EO parameters found in the literature review, it was decided to classify the EO parameters into four main categories that encompass the data, information, and products identified. The EO parameters were classified into four main categories that influence the disease transmission (Figure 3).

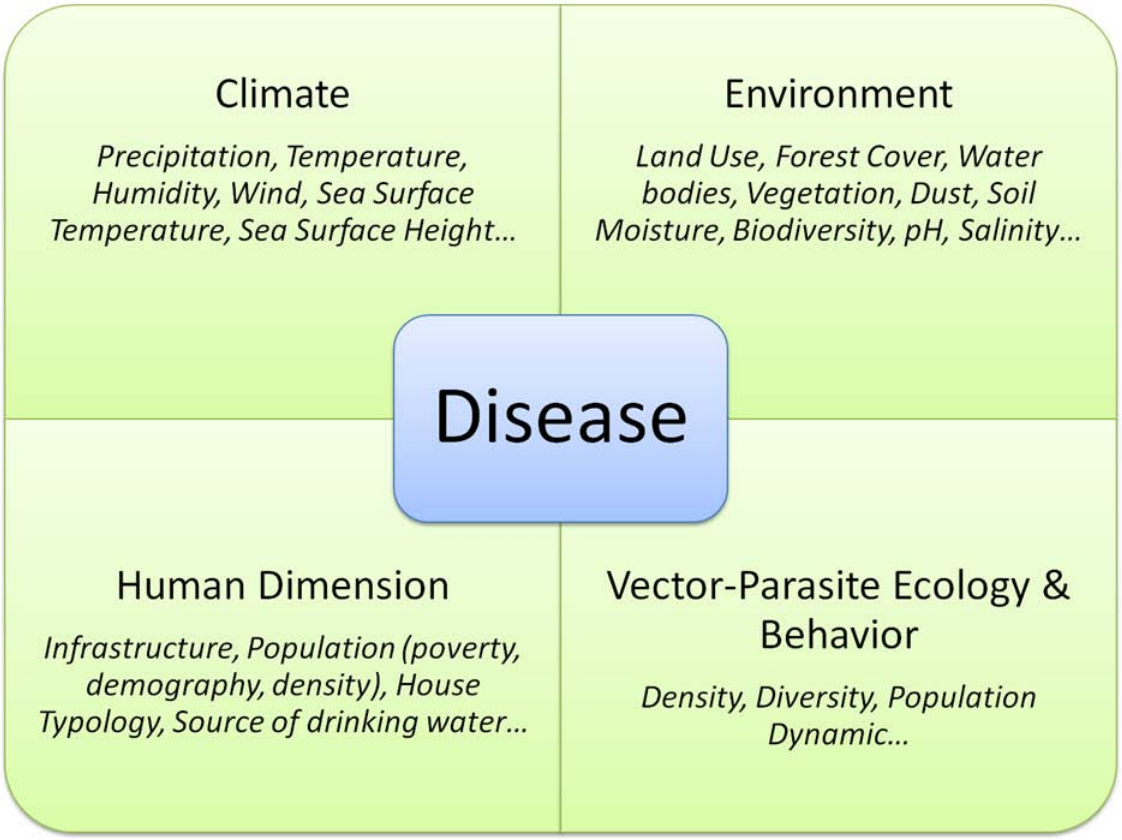

Figure 3: Epidemiological System Showing the Four Main Categories of EO Parameters which Are Analyzed in this Document

4 Earth Observations for Health SBA- Infectious Diseases Sub-Area

This section contains the results from the extensive document review and the specific observation parameters/characteristics that the analysis revealed for the Vector-Borne Diseases and Non-Vector-Borne Diseases.

4.1 Earth Observations for Vector-Borne Diseases

Table 9 lists the observations for the subarea Vector-Borne Diseases. These include in-situ, airborne, and satellite observations identified through the literature review.

Table 9: EO Parameters for Human Health Vector-Borne Infectious Diseases

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Disease
Observation Category: Climate							
Precipitation	**1. In-situ:** • Data: Weather stations managed by the National Meteorological and Hydrological Services • Products: Gridded data products derived from station observations (*e.g.,* DAYMET, WORDLCLIM)	Local. Extent depends on the country infrastructure established by the Met Services, sometimes supplemented by rain gauges installed by the Ministry of Health	Local measure ment	Hourly, daily, 7-days, 10-days, monthly data	N/A	Depends on the met services (from real time to days/ months later)	Malaria, Trypanosomiasis, Chagas, Leishmaniasis, African eye worm, Lymphatic filariasis, Dengue, Rift Valley fever, Yellow fever, St. Louis encephalitis, Japanese encephalitis, Murray Valley encephalitis, Ross River virus, Kunjin virus, West Nile fever, Lyme disease, Plague, Chikungunya, Barmah Forest virus, Blue tongue, Trachoma, Guinea worm
Precipitation	**2. Satellite:** (*e.g.,* GOES, Meteosat, GMS, GOMS, TRMM, SSMI, INSAT)	Subnational,			Depends on the region, time-scale, products used (see Dinku *et al.*	Almost real time (daily to	Malaria, Trypanosomiasis, Leishmaniasis, Dengue, Rift Valley fever, Plague, Chikungunya, Lyme disease

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Disease
	• Data: VS, IR, TIR, PM channels • Information: Rainfall estimate (*e.g.*, CCD, CMAP, CMOPRH, RFE) • Product: Rainfall anomalies	national, regional continental to global	11km, 0.25°, 0.5°, 1°, 2.5° (for rainfall estimate)	3-hourly, daily, 10-day, monthly data	2008a, b; Dinku *et al.* 2007 for more precision on accuracy)	three days after the last satellite acquisi-tion)	
Air temperature	**1 In-situ:** • Data: Tmin, Tmax, Tmean	Subnational, national, regional continental to global	Local measure ment	Hourly, daily, 7-days, 10-days, monthly data	N/A	Depends on the met services (from real time to days/ months later).	Malaria, Trypanosomiasis, Chagas, Leishmaniasis, Onchocercasis, African eye worm, Dengue, Rift Valley fever, St. Louis encephalitis, Japanese encephalitis, Murray valley encephalitis, Ross river virus, Kunjin virus, West Nile fever, Lyme disease, Plague, Chikungunya, Barmah Forest virus, Blue tongue, Trachoma,

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	**Coverage/ Extent**	**Spatial**	**Temporal**	**Accuracy**	**Latency**	**Disease**
Air temperature	**2. Models:** • Product: Temperature forecast (from GCM model outputs)	Regional and global	2.8 deg for rainfall forecast products	Temperature forecast 3-6 months lead time		Monthly temp. forecast products	
Humidity (absolute and relative)	**1. In-situ:** • Data Weather stations managed by the National Meteorological and Hydrological Services	Local. Extent depends on the country infrastructure established by the Met Services	Local measure-ment	Hourly, daily, 7-days, 10-days, monthly data	N/A	Depends on the met services (from real-time to days, weeks, months later	Malaria, Chagas, Leishmaniasis, Dengue, Japanese encephalitis, Murray valley encephalitis, Ross river virus, West Nile fever, Plague, Chikungunya, Barmah Forest virus, Blue tongue, Trachoma
Wind	**1. In-situ**: • Data: Weather stations managed by the National Meteorological and Hydrological	Local, regional to global	Local	N/A	N/A	N/A	Rift Valley fever, Blue tongue

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	**Coverage/ Extent**	**Spatial**	**Temporal**	**Accuracy**	**Latency**	**Disease**
	Services **2. Models:** • Products: From ECMWF		0.5 by 0.5 deg for model output				
Sea surface temperature	**1. In-situ:** • Data: Buoys (*e.g.*, National Data Buoy Center (NDBC)) **2. Satellite:** • Data: TIR channels • Information: ENSO, ONI, SOI, PDO, NAO, IOI • Product: Sea surface anomalies **3. Models:**	Regional	N/A	N/A	N/A	N/A	Malaria, Chagas, Leishmaniasis, Dengue, Rift Valley fever, Murray valley encephalitis, Ross river virus, Lyme disease

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	**Coverage/ Extent**	**Spatial**	**Temporal**	**Accuracy**	**Latency**	**Disease**
	• Products: ENSO forecast based on GCM models						
Sea surface height	1 **In situ:** • Data: High/low tide	N/A	N/A	N/A	N/A	N/A	Murray valley encephalitis, Ross river virus, Kunjin virus, Barmah Forest virus
Observation Category: Environment							
Land use/ land cover	**1. In situ: N/A** **2. Satellite:** (*e.g.,* ALOS-AVNIR-2, SPOT-5, Landsat, Terra-MODIS,Terra-ASTER, Orbview-2 SeaWiFS, RADARSAT) • Data: Red, NIR, MIR	N/A	25 m to 8 km	N/A	N/A	N/A	Malaria, Trypanosomiasis, Leishmaniasis, Onchocercasis, African eye worm, Dengue, St. Louis encephalitis, West Nile fever, Lyme disease, Plague, Blue tongue

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Disease
	channels, SAR • Products: Land use/ land cover maps (*e.g.,* produced by USGS, JRC, CORINE)						
Forest cover	**1. In situ:** • Data: Forest distribution (Lyme disease) **2. Satellite:** • Products: Forest cover (*e.g.,* from TREES JRC and USGS)	N/A	1 km (for TREES JRC product)	N/A	N/A	N/A	Malaria, Onchocercasis, African eye worm, Lyme disease, Plague
Water bodies	**1. In situ:** • Data: Stored water, rivers,	Local, regional	High resolu-tion (10 m from SPOT), 250 m to	Daily to monthly (depending on revisiting time of satellite and	N/A	MODIS daily images available in almost real time	Malaria, Onchocercasis, Dengue, Rift Valley fever, Japanese encephalitis, Murray valley encephalitis, Ross river virus, West Nile fever, Lyme disease, Chikungunya, Blue tongue,

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Disease
	• Information: Distance to rivers (Onchocercasis) **2. Satellite:** (*e.g.,* NOAA_AVHRR, SPOT-VEGETA-TION, Landsat TM, SPOT-5) • Data: VS, IR, MIR channels • Information: NDWI, NDTI, NDPI • Product: ZPOM		1 km (from MODIS)	cloud cover		to a few days after acquisition	Plague, Guinea worm
Vegetation	**1. In situ: N/A** **2. Satellite:** (*e.g.*, SPOT, LANDSAT TM ETM MSS, MODIS, NOAA-AVHRR, SPOT-VEGETATION)	Local, regional, global	10 m with SPOT, 30 m with LANDSAT, 250 m with MODIS to 8 km with	Daily to monthly (depending on revisiting time of satellite and cloud cover)	N/A	Available in almost real time to a few days after acquisition	Malaria, Trypanosomiasis, Chagas, Leishmaniasis, Onchocercasis, African eye worm, Dengue, Rift Valley fever, Murray valley encephalitis, Ross river virus, West Nile fever, Lyme disease, Plague, Chikungunya, Blue tongue, Crimean-congo hemorrhagic fever

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Disease
	• Data: Blue, VS, IR, channels • Information: (*e.g.*, NDVI, NDWI, LAI, SAVI, GVI, MSAVI, GEMI, EVI) • Product: Vegetation status, vegetation greenness, and vegetation moisture anomalies		AVHRR				
Soil moisture	1. **In situ: N/A** 2. **Satellite (as potential):** (*e.g.,* AMSR-E, SSMI) potential • Data: PM channels • Information: Soil moisture	Local, regional to global	15-50 km	Hourly, Daily to Monthly	N/A	Available in almost real time to a few days after acquisition	Lyme disease

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Disease
	maps • Product: Soil moisture anomalies 3. **Models (as potential):** • Information: Output from Land Parameter Retrieval Model (LPRM)						
Soil type	**1. In situ: N/A**	N/A	N/A	N/A	N/A	N/A	Leishmaniasis, Lyme disease, Plague, Ross river virus
Deforestation	**1. In situ: N/A** **2. Satellite: (***e.g.* SPOT, LANDSAT TM ETM MSS, MODIS, NOAA-AVHRR, SPOT-VEGETA-TION)	Local, regional, global	10m with SPOT, 30 m with LANDSAT, 250m with MODIS to 8km with AVHRR	N/A	N/A	N/A	Onchocercasis, Plague

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Disease
	• Data: Blue, VS, IR, channels • Information: (*e.g.,* NDVI) • Product: Deforestation map (*e.g.,* TREES - JRC)						
Biodiversity	**1. In situ:** • Data: Habitat classification, habitat type, dominant trees, indicator species	N/A	N/A	N/A	N/A	N/A	Lyme disease
pH and salinity of soil	**1. In situ: N/A**	N/A	N/A	N/A	N/A	N/A	Murray valley encephalitis, Ross river virus, Kunjin virus
Topography	**1. In situ:** • Data: Elevation, slope, depression	N/A	30 to 90 m	N/A	N/A	N/A	Malaria, Chagas, Leishmaniasis, African eye worm, Dengue, Lyme disease, Plague, Blue tongue

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Disease
	2. **Satellite:** • Information: SRTM, elevation from USGS product						
Observation Category: Human Dimension							
Infrastructure (hospital, health facilities, sewage treatment, cold rooms for vaccines and drugs) dams, wells, sanitation facilities, Urbanization; refugee camps	**1. In situ:** • Data: (*e.g.,* Transportation (for Chikungunya) Garbage collection (Leishmaniasis) , habitat characteristic, use of bed nets, type of roof) 2. **Satellite:** (*e.g.*, Orbview-3, Ikonos, Quickbird-2)	N/A	1 m	N/A	N/A	N/A	Malaria, Leishmaniasis, Lymphatic filariasis, Dengue, West Nile fever, Lyme disease, Chikungunya

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Disease
	• Data: PAN, VIS, NIR channels • Information: Urban maps						
Demographic (population density, population distribution, age structure, gender)	**1. In situ:** • Data: *(e.g.,*census data, human susceptibility, movement of population, education, family income) Product: Gridded population data, global distribution of poverty, infant mortality (CIESIN)	Local, district level, regional, global	Local, 2.5 arc-minute grid box	N/A	N/A	N/A	Malaria, Trypanosomiasis, Chagas, Leishmaniasis, Onchocercasis, Lymphatic filariasis, Dengue, Rift Valley fever, Murray valley encephalitis, Ross river virus, West Nile fever, Lyme disease, Chikungunya
Observation Category: Vector: Parasite Ecology and Behavior							
Vector population, abundance,	**1. In situ:** • Data: (*e.g.,*	N/A	N/A	N/A	N/A	N/A	Malaria, Trypanosomiasis, Chagas, Dengue, Rift Valley fever, Yellow fever, St. Louis encephalitis,

Parameter		Characteristics of the Observations Parameters					
	Data-Information - Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Disease
suitable habitat	mosquito abundance, density; pig density (Japanese encephalitis), tick population and small mammal distribution (Lyme disease), marsupial population (Ross river virus); dead crow (West Nile Fever))						Japanese encephalitis, Murray valley encephalitis, Ross river virus, West Nile fever, Lyme disease, Plague, Blue tongue, Crimean-congo hemorrhagic fever, Guinea worm
Pathogen Population Dynamic	**1. In situ: N/A**	N/A	N/A	N/A	N/A	N/A	Malaria, Dengue, Ross river virus,

N/A = not available

4.2 Earth Observations for Non-Vector-Borne Diseases

Table 10: EO Parameters for Human Health Non-Vector-Borne Infectious Diseases

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	**Coverage/ Extent**	**Spatial**	**Temporal**	**Accuracy**	**Latency**	**Other**
Observation Category: Climate							
Precipitation	**1. In-situ:** • Data: Weather stations managed by the National Meteorological and Hydrological Services • Products Gridded data products derived from station observations (*e.g.,* DAYMET, WORDLCLIM)	Local: Extent depends on the country infrastruc-ture established by the Met Services, sometimes supple-mented by rain gauges installed by the Ministry of Health	Local mea-sure-ment	Hourly, daily, 7-days, 10-days, monthly data	N/A	Depends on the met services (from real time to days, weeks, months later)	Hemorrhagic fever with renal syndrome, Hantavirus, Toxoplasmosis, Leptospirosis, Acute respiratory virus, Meningococcal meningitis, Diarrheal diseases, Cholera, Salmonella, Influenza, Ebola Hemorrhagic fever, Hookworm, Shigellosis, Fasciolosis, Schistosomiasis
Precipitation	**2. Satellite:** (*e.g.,* GOES, Meteosat, GMS, GOMS, TRMM, SSMI, INSAT) • Data: VS, IR, TIR, PM channels	Sub-national, national,			Depends on the region, time-scale, products used (see Dinku *et al.* 2008a, b; Dinku *et al.*	Almost real time	Meningococcal meningitis, Diarrheal diseases, Cholera, Influenza, Schistosomiasis

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Other
	• Information: Rainfall estimate (*e.g.*, CCD, CMAP, CMOPRH, RFE) • Product: Rainfall anomalies **3. Models:** • Product: Rainfall forecast (from GCM model outputs)	regional continental to global Regional and global	11km, 0.25°, 0.5°, 1°, 2.5° (for rainfall esti-mate 2.8 deg for rainfall forecast pro-ducts	3-hourly, daily, 10-day, monthly data; Rainfall forecast 3-6 months lead time	2007 for more precision on accuracy)	(daily to three days after the last satellite acquisi-tion Monthly rainfall forecast products	
Air temperature	**1. In-situ:** • Data: Tmin, Tmax, Tmean	Sub-national, national, regional continental to global	Local mea-sure-ment	Hourly, daily, 7-days, 10-days, monthly data	N/A	Depends on the met services (from real time to days, weeks, months	Hemorrhagic fever with renal syndrome, Hantavirus, Toxoplasmosis, Leptospirosis, Acute respiratory virus, Meningococcal meningitis, Diarrheal diseases, Cholera, Salmonella, Influenza, Amoebiasis,

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Other
						later)	Hookworm, Shigellosis, Rotavirus, Fasciolosis, Schistosomiasis
Air temperature and land surface temperature	**2. Satellite:** (*e.g.,* NOAA-AVHRR, METEOSAT, MODIS) • Data: TIR channel • Information: LST night time corresponding to min air temp; LST day time images • Product: Derived air temperature from LST night and LST daytime **3. Models:** • Product: Temperature forecast (from GCM model outputs)	National, regional continental to global Regional and global	1 km, 5 km 2.8 deg for rainfall forecast products	Daily, 8-day, monthly Temperature forecast 3-6 months lead time	Depends on the region and time scale (Vancutsem *et al*. 2010 for more precision on accuracy)	Real time to a few days after satellite overpass Monthly temp. forecast products	Hemorrhagic fever with renal syndrome, Meningococcal meningitis, Cholera, Schistosomiasis

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	**Coverage/ Extent**	**Spatial**	**Temporal**	**Accuracy**	**Latency**	**Other**
Humidity (absolute and relative)	**1. In-situ:** • Data: Weather stations managed by the National Meteorological and Hydrological Services	Local. Extent depends on the country infrastruc-ture established by the Met Services	Local mea-sure-ment	Hourly, daily, 7-days, 10-days, monthly data	N/A	Depends on the met services (from real time to days, weeks, months later	Hemorrhagic fever with renal syndrome, Hantavirus, Leptospirosis, Acute respiratory virus, Meningococcal meningitis, Diarrheal diseases, Cholera, Salmonella, Influenza, Amoebiasis, Shigellosis, Rotavirus, Schistosomiasis
Wind	**1. In-situ**: • Data: Weather stations managed by the National Meteorological and Hydrological Services	Local	Local	N/A	N/A	N/A	Hemorrhagic fever with renal syndrome, Acute respiratory virus, Diarrheal diseases, Cholera, Meningococcal meningitis, Salmonella
Sea surface temperature	**1. In-situ:** • Data: (*e.g.,* from buoys, *e.g.* National Data Buoy Center (NDBC)) **2. Satellite:**	Regional	N/A	N/A	N/A	N/A	Hantavirus, Acute respiratory virus, Cholera, Influenza,

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Other
	• Data: TIR channels • Information: ENSO, ONI, SOI, PDO, NAO, IOI • Product: Sea surface anomalies **3. Models:** • Product: ENSO forecast based on GCM models						
Sea surface height	**1. Satellite:** (TOPEX/Poseidon)	N/A	N/A	N/A	N/A	N/A	Acute respiratory virus, Cholera
Sunshine duration, solar radiation	**1. In situ: N/A**	N/A	N/A	N/A	N/A	N/A	Salmonella, Hemorrhagic fever
Observation Category: Environment							
Dust	1. **In situ**: AERONET data 2. **Satellite**: *(e.g.,* MODIS MISR, TOMS) • Data: Blue, green, red, NIR channels	Local to gobal	0.25 deg by 0.25deg to 1.25 deg	Daily to monthly	N/A	N/A	Acute respiratory virus, Meningococcal meningitis

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Other
	• Information Aerosol optical thickness, angstrom exponent, dust fraction						
Water bodies	**1. In situ:** • Data: Aquifers, ground water quality, hydrological features **2. Satellite**: (*e.g.,* NOAA_AVHRR, SPOT-VEGETATION, Landsat TM, SPOT-5) • Data: VS, IR, MIR channels • Information: NDWI, NDTI, NDPI • Product: ZPOM	Local, regional	High resolu-tion (10 m from SPOT), 250 m to 1 km (from MODIS	Daily to monthly (depending on revisiting time of satellite and cloud cover	N/A	MODIS daily images available in almost real time to a few days after acquisi-tion	Hemorrhagic fever with renal syndrome, Hantavirus, Toxoplasmosis, Leptospirosis, Acute respiratory virus, Diarrheal diseases, Cholera, Rotavirus, Typhoid, Schistosomiasis
Vegetation	**1. In situ: N/A** 2 **Satellite:** (*e.g.*, SPOT, LANDSAT TM ETM MSS, MODIS, NOAA-	Local, regional, global	10 m with SPOT, 30 m with LANDS	Daily to monthly (depending on revisiting time of satellite and	N/A	Available in almost real time to a few days after	Hemorrhagic fever with renal syndrome, Hantavirus, Toxoplasmosis, Acute respiratory virus, Diarrheal diseases, Cholera, Ebola

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Other
	AVHRR, SPOT-VEGETATION) • Data: Blue, VS, IR, channels • Information: (*e.g.,* NDVI, NDWI, LAI, SAVI, GVI, MSAVI, GEMI, EVI) • Product: Vegetation status, vegetation greenness, and vegetation moisture anomalies		AT, 250 m with MODIS to 8 km with AVHRR	cloud cover)		acquisi-tion	Hemorrhagic fever, Ascariasis, Fasciolosis, Schistosomiasis
Soil moisture	**1. In situ: N/A**	N/A	N/A	N/A	N/A	N/A	Hantavirus, Schistosomiasis
Soil type	**1. In situ: N/A**	N/A	N/A	N/A	N/A	N/A	Hookworm, Meningococcal meningitis, Schistosomiasis
Land use/ Land cover	**1. In situ: N/A** **2. Satellite:** (*e.g.,* ALOS-AVNIR-2, SPOT-5, Landsat, Terra-MODIS,Terra-ASTER, Orbview-2 SeaWiFS, RADARSAT)	Local, regional, global	25 m to 8 km	N/A	N/A	N/A	Hemorrhagic fever with renal syndrome, Hantavirus, Toxoplasmosis, Leptospirosis, Acute respiratory virus, Meningococcal meningitis, Cholera, Schistosomiasis

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Other
	• Data: Red, NIR, MIR channels, SAR • Products: Land use/ land cover maps (*e.g.,* produced by USGS, JRC)						
pH	**1. In situ: N/A**	N/A	N/A	N/A	N/A	N/A	Cholera, Schistosomiasis
Salinity	**1. In situ: N/A**	N/A	N/A	N/A	N/A	N/A	Cholera
Algal blooms/Ocean color	1. **In situ:** (Measurements on board ships) **2. Satellite** (*e.g.,* MODIS, SeaWiFS) • Data: VIS, NIR channels • Information: Chlorophyll concentration	Local, regional, global	250 m to 1.1 km	Daily to monthly	N/A	N/A	Cholera
Biodiversity	**1. In situ:** • Data: Bird species (SARS, Avian flu)						Acute respiratory virus,

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Other
Topography	**1. In situ:** • Data: Elevation, slope 2. **Satellite:** • Information: SRTM, elevation from USGS product	N/A	30 to 90 m	N/A	N/A	N/A	Hemorrhagic fever with renal syndrome, Acute respiratory virus, Hantavirus, Leptospirosis, Schistosomiasis
Observation Category: Human Dimension							
Infrastructure/ Urbanization (wells, latrines, sanitation). Refugee camp	**1. In situ:** • Data: Number of farms, transportation routes, hospitals, movement of population (*HIV-AIDS, also related to natural disasters: flood, drought and war*), air travel (Influenza), type of housing **2. Satellite:** (*e.g.*, Orbview-3, Ikonos, Quickbird-2)	N/A	1 m	N/A	N/A	N/A	Leptospirosis, Acute respiratory virus, Hantavirus, Meningococcal meningitis, Diarrheal diseases, Cholera, Influenza, HIV-AIDS, Ascariasis, Shigellosis, Rotavirus, Typhoid

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Other
	• Data: PAN, VIS, NIR channels • Information: Urban maps						
Population density/ vulnerability	**1. In situ:** • Data: *(e.g.,* Census data, settlements of population, movement of population) • Product: Gridded population data, global distribution of poverty, infant mortality (CIESIN/SEDAC)	Local, district level, regional, global	Local, 2.5 arc-minute grid box	N/A	N/A	N/A	Hantavirus, Meningococcal meningitis, Rotavirus, HIV/AIDS, Diarrheal diseases, Cholera, Influenza, Shigellosis,
Source of drinking water	1. **In situ:** Data: Wells location	N/A	N/A	N/A	N/A	N/A	Ascariasis, Diarrheal diseases, Cholera
Access to health care	**1. In situ: N/A**	N/A	N/A	N/A	N/A	N/A	Diarrheal diseases, Cholera

Parameter		Characteristics of the Observations Parameters					
	Products (in-situ - airborne - satellite)	Coverage/ Extent	Spatial	Temporal	Accuracy	Latency	Other
Observation Category: Host Ecology and Behavior							
Distribution and density of susceptible animal hosts	**1. In situ:** • Data: Bird migration, poultry movement (avian flu); elk population size and elk feeding data (Brucella), snail survey (Fasciolosis), Distribution and prevalence of deer mice (Hantavirus), snail distribution (Shistosomiasis); presence of rodents, felines (for Toxoplasmosis)	N/A	N/A	N/A	N/A	N/A	Acute respiratory virus, Hantavirus, Brucella, Fasciolosis, Leptospirosis, Schistosomiasis, Toxoplasmosis

N/A = not available

In addition to the EO parameters derived from satellite listed in Tables 9 and 10, it is worth mentioning some of the future satellite missions currently planned for launch in the next decade (particularly SMAP, LDCM, NPP, NPOESS, and HyspIRI) which will provide relevant information on soil moisture, vegetation, and land use/land cover.

5 Priority Earth Observations for Human Health Infectious Disease SBA

5.1 Priority Observations

This section contains the specific priority Earth observations for the Health SBA-Infectious Diseases Sub-Area.

Based on the burden diseases and corresponding EO parameters (see Table 11), the EO parameters were ranked using the cumulative impact equation presented in section 2.3.3.

Table 11: Priority Observations for Health SBA- Infectious Diseases Sub-Area: Diseases Burden Classification

GEO Task US-09-01a: Priority Earth Observations for Health SBA-Infectious Diseases Sub-Area Disease Burden Classification		
Diseases	**EO Parameter**	**Global Burden (1000 DALYs)**
HIV AIDS	Population density, population movement resulting from natural disasters	95 805
Influenza (Acute respiratory virus)	Precipitation, temperature, humidity, wind, sea surface temperature, sea surface height, dust, water bodies, urbanization, population density, vector population (bird migration), land use, vegetation, topography, biodiversity	94 603
Diarrheal diseases (incl. cholera)	Precipitation, temperature, humidity, wind, water bodies, land use, urbanization, sea surface temperature, sea surface height, vegetation, land use, salinity, infrastructure (wells, latrines), algal blooms, pH, population density, source of drinking water, access to health care	61 966
Malaria	Precipitation, temperature, humidity, sea surface temperature, land use, forest cover, topography, infrastructure, population density, vegetation, water bodies, vector population, pathogen population dynamic	46 486
Meningococcal meningitis	Precipitation, temperature, humidity, wind, dust, land use, soil type, infrastructure, population	6 192

GEO Task US-09-01a: Priority Earth Observations for Health SBA-Infectious Diseases Sub-Area Disease Burden Classification		
Diseases	**EO Parameter**	**Global Burden (1000 DALYs)**
	density	
Lymphatic filariasis	Precipitation, infrastructure, population density	5 777
Intestinal nematodes (Ascariasis, Hookworm)	Precipitation, vegetation, soil type, infrastructure, source of drinking water	2 951
Trachoma	Precipitation, temperature, humidity	2 329
Leishmaniasis	Precipitation, temperature, humidity, sea surface temperature, land use, vegetation, soil type, topography, infrastructure, population density	2 090
Schistosomiasis	Precipitation, temperature, humidity, water bodies, vegetation, land use, urbanization, soil moisture, soil type, pH, topography, distribution of animal host	1 702
Africa Trypanosomiasis	Precipitation, temperature, land use, vegetation, population density, vector population	1 525
Japanese encephalitis	Precipitation, temperature, humidity, water bodies, vector population	709
Chagas disease (American trypanosomiasis)	Precipitation, temperature, humidity, sea surface temperature, vegetation, topography, population density, vector population	667
Dengue	Precipitation, temperature, humidity, sea surface temperature, water bodies, vegetation, topography, land use, infrastructure, population density, vector population	616
Onchocerciasis	Temperature, land use, vegetation, water bodies, forest cover, deforestation, population density	484
St Louis encephalitis	Precipitation, temperature, land use, vector population	Unquantified: 1
Rift Valley Fever	Precipitation, temperature, wind, water bodies, vegetation, sea surface temperature	Unquantified: 1
West Nile Fever	Precipitation, temperature, humidity, water bodies, land use, urbanization, vegetation, population density, vector population	Unquantified: 1
Ross River Virus	Precipitation, temperature, humidity, sea surface temperature, sea surface height, water bodies, vegetation, soil type, pH and salinity of soil, population density, vector population, pathogen population dynamic	Unquantified: 1
Murray Valley fever	Precipitation, temperature, humidity, sea surface temperature, sea surface height, water bodies, vegetation, pH and salinity of soil, population	Unquantified: 1

GEO Task US-09-01a: Priority Earth Observations for Health SBA-Infectious Diseases Sub-Area Disease Burden Classification		
Diseases	**EO Parameter**	**Global Burden (1000 DALYs)**
	density, vector population	
Lyme disease	Precipitation, temperature, sea surface temperature, land use, forest cover, water bodies, vegetation, soil moisture, soil type, biodiversity, topography, urbanization, population density, vector population	Unquantified: 1
Yellow fever	Precipitation, vector abundance	Unquantified: 1
Ebola	Precipitation, vegetation	Unquantified: 1
Plague	Precipitation, temperature, humidity, land use, forest cover, water bodies, vegetation, soil type, deforestation, topography, vector population	Unquantified: 1
Salmonella	Precipitation, temperature, humidity, wind, sunshine duration, solar radiation	Unquantified: 1
Hemorrhagic fever	Precipitation, temperature, humidity, wind, water bodies, vegetation, topography, sunshine duration, solar radiation	Unquantified: 1
Hemorrhagic fever with renal syndrome	Precipitation, temperature, humidity, vegetation, land use, topography, sunshine duration, solar radiation	Unquantified: 1
Hantavirus	Precipitation, temperature, humidity, sea surface temperature, water bodies, vegetation, land use, soil moisture, topography, urbanization, population density, distribution of animal hosts	Unquantified: 1
Kunjin virus	Precipitation, temperature, sea surface height, pH and salinity of soil	Unquantified: 1
Brucella	Distribution and density of susceptible animal hosts	Unquantified: 1
Toxoplasmosis	Precipitation, temperature, water bodies, vegetation, land use, distribution and density of susceptible animal hosts	Unquantified: 1
Leptospirosis	Precipitation, temperature, humidity, water bodies, land use, topography, infrastructure, distribution and density of susceptible animal hosts	Unquantified: 1
Chikungunya	Precipitation, temperature, humidity, water bodies, vegetation, infrastructure, population density	Unquantified: 1
Barmah forest virus	Precipitation, temperature, humidity, sea surface height	Unquantified: 1
Blue tongue	Precipitation, temperature, humidity, wind, water bodies, land use, vegetation, topography, vector population	Unquantified: 1
Crimean-congo hemorrhagic fever	Vegetation, vector population	Unquantified: 1

GEO Task US-09-01a: Priority Earth Observations for Health SBA-Infectious Diseases Sub-Area Disease Burden Classification		
Diseases	**EO Parameter**	**Global Burden (1000 DALYs)**
Fasciolosis	Precipitation, temperature, vegetation, distribution and density of susceptible animal hosts	Unquantified: 1
Amoebiasis	Temperature, humidity	Unquantified: 1
Shigellosis	Precipitation, temperature, humidity, infrastructure, population density	Unquantified: 1
Guinea worm	Precipitation, water bodies, vector abundance	Unquantified: 1
Rotavirus	Temperature, humidity, water bodies, infrastructure, population density	Unquantified: 1
Typhoid	Water bodies, infrastructure	Unquantified: 1
African eye worm	Precipitation, temperature, vegetation, land use, forest cover, topography	Unquantified: 1

Table 12, Table 13, Table 14, and Table 15 show the results of the EO ranking specifically for the Climate, Environment, Human Dimension and Vector Ecology and Behavior categories as defined in Section 3.4.2.

Table 12: Ranking of Climate Information

GEO Task US-09-01a: Priority Earth Observations for Health SBA-Infectious Diseases Sub-Area Climate Category		
EO Parameter	**Data – Information - Products**	**Ranking (Cumulative Impact)**
Precipitation (*R*)	1. In situ: • Data: Weather stations • Products: Gridded data 2. Satellite: • Data: VS, IR, TIR, PM channels • Information: Rainfall estimates • Products: Rainfall anomalies 3. Models: • Rainfall forecast	$R_{imp} = 94603 + 61966 + 46486 + 6192 + 5777 + 2951 + 2329 + 2090 + 1702 + 1525 + 709 + 667 + 616 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1$ $R_{imp} = 227636$
Temperature (*T*)	1. In situ: • Data: Weather stations (Tmin, Tmean, Tmax)	

GEO Task US-09-01a: Priority Earth Observations for Health SBA-Infectious Diseases Sub-Area <u>Climate Category</u>		
EO Parameter	**Data – Information - Products**	**Ranking (Cumulative Impact)**
	2. Satellite: • <u>Data</u>: TIR channels • <u>Information</u>: Land Surface Temperature (LST) • <u>Products:</u> Air temperature derived from LST, temperature anomalies, 3. Models: • <u>Products</u>: Temperature forecast	$T_{imp} = 94603 + 61966 + 46846 + 6192 + 2329 + 2090 + 1072 + 1525 + 709 + 667 + 616 + 484 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1$ $T_{imp} = 219121$
Humidity (*H*)	1. In situ: • <u>Data</u>: Weather stations (absolute, relative humidity)	$H_{imp} = 94603 + 61966 + 46486 + 6192 + 2329 + 2090 + 1702 + 709 + 667 + 616 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1$ $RH_{imp} = 217375$
Sea Surface Temperature (*SST*)	1. In-situ: • <u>Data</u>: From buoys 2. Satellite: • <u>Data</u>: TIR channels • <u>Information</u>: ENSO, ONI, SOI, PDO, NAO, IOI • <u>Products</u>: Sea surface anomalies 3. Models: • <u>Products</u>: ENSO forecast model forecast output	$SST_{imp} = 94603 + 61966 + 46486 + 2090 + 667 + 616 + 1 + 1 + 1 + 1 + 1$ $SST_{imp} = 206433$
Wind (*W*)	1. In situ: • <u>Data</u>: Weather stations 2. Model: • <u>Products:</u> Wind output from ECMWF	$W_{imp} = 94603 + 61966 + 6192 + 616 + 1 + 1 + 1$ $W_{imp} = 163380$
Sea Surface Height (*SSH*)	1. In situ: **N/A** 2. Satellite: (Topex/Poseidon)	$SSH_{imp} = 94603 + 61966 + 1 + 1 + 1 + 1$ $SSH_{imp} = 156573$
Sunshine duration/ solar radiation (*Sun_d*)	1. In situ: **N/A**	$Sun_d = 1 + 1 + 1$ $Sun_d = 3$

Table 13: Ranking of Environmental Information

GEO Task US-09-01a: Priority Earth Observations for Health SBA-Infectious Diseases Sub-Area Environmental Category		
EO Parameter	**Data – Information - Products**	**Ranking (Cumulative Impact)**
Land Use (*LU*)	1. In situ: **N/A** 2. Satellite: • Data: VS, IR, MIR, TIR channels, SAR • Products: Land use/land cover maps	$LU_{imp} = 94603 + 61966 + 46486 + 6192 + 2090 + 1702 + 1525 + 616 + 484 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1$ $LU_{imp} = 215674$
Vegetation (*V*)	1. In situ: **N/A** 2. Satellite: • Data: Blue, VS, IR, TIR channels • Information: NDVI, NDWI, LAI, SAVI, GVI, GEMI, EVI, MSAVI • Products: Vegetation status, vegetation greenness, and vegetation moisture anomalies	$V_{imp} = 94603 + 61966 + 46486 + 2951 + 2090 + 1702 + 1525 + 667 + 616 + 484 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1$ $V_{imp} = 213106$
Water Bodies (*WB*)	1. In situ: • Data: Stored water, rivers, aquifers, ground water quality • Information: Distance to rivers 2. Satellite: • Data: VS, IR, TIR channels • Information: NDWI, NDTI • Products: Water body areas	$WB_{imp} = 94603 + 61966 + 46486 + 1702 + 709 + 616 + 484 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1$ $WB_{imp} = 206581$
Topography (*Tp*)	1. In situ: • Data: Elevation, slope, depression 2. Satellite: • Information: SRTM, elevation from USGS	$Tp_{imp} = 94603 + 46486 + 2090 + 1702 + 667 + 616 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1$ $Tp_{imp} = 146172$
Dust (*Ds*)	1. In situ: • Data: AERONET data 2. Satellite: • Data: Blue, green, red, NIR channels • Information: Aerosol optical thickness, angstrom exponent, dust fraction	$Ds_{imp} = 94603 + 6192$ $Ds_{imp} = 100795$

GEO Task US-09-01a: Priority Earth Observations for Health SBA-Infectious Diseases Sub-Area Environmental Category		
EO Parameter	**Data – Information - Products**	**Ranking (Cumulative Impact)**
Biodiversity (*B*)	1. In situ: • Data: Habitat classification, habitat type, dominant trees, indicator species (*e.g.*, birds)	$B_{imp} = 94603 + 1$ $B_{imp} = 94604$
pH (*pH*)	1. In situ: **N/A**	$pH_{imp} = 61966 + 1702 + 1 + 1 + 1$ $pH_{imp} = 63671$
Salinity (*S*)	1. In situ: **N/A**	$S_{imp} = 61966 + 1 + 1 + 1$ $S_{imp} = 61969$
Algal Blooms/Ocean Color (*AOC*)	1. In situ: **N/A** 2. Satellite: • Data: VS, NIR channels • Information: Chlorophyll concentration	$AOC_{imp} = 61966$
Forest Cover (*FC*)	1. In situ: • Data: Forest distribution 2. Satellite: • Products: Forest maps (TREES project JRC and USGS)	$FC_{imp} = 46486 + 484 + 1 + 1 + 1$ $FC_{imp} = 46973$
Soil Type (*ST*)	1. In situ: **N/A**	$ST_{imp} = 6192 + 2951 + 2090 + 1702$ $+1 + +1 + 1$ $ST_{imp} = 12938$
Soil Moisture (*SM*)	1. In situ: **N/A** 2. Satellite (as potential): • Data: PM channels • Information: Soil moisture maps • Products: Soil moisture anomalies 3. Model (as potential): • Information: Soil moisture maps derived from LPRM model	$SM_{imp} = 1702 + 1 + 1$ $SM_{imp} = 1704$
Deforestation (*D*)	1. In situ: **N/A** 2. Satellite (as potential): • Data: Blue, VS, IR channels • Information: NDVI • Products: Deforestation maps	$D_{imp} = 484 + 1$ $D_{imp} = 485$

Table 14: Ranking of Human Dimension Information

GEO Task US-09-01a: Priority Earth Observations for Health SBA-Infectious Diseases Sub-Area Human Dimension Category		
EO Parameter	**Data – Information - Products**	**Ranking (Cumulative Impact)**
Population Density (*PD*)	1. In situ: • Data: (*e.g.,* census data, settlements of population, movement of population) • Product: Gridded population data, global distribution of poverty, infant mortality (*e.g.,* CIESIN/SEDAC)	$PD_{imp} = 95805 + 94603 + 46486 + 61966 + 46486 + 6192 + 5777 + 2090 + 1525 + 667 + 616 + 484 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1$ $PD_{imp} = 362705$
Infrastructure/ Urbanization (*I/U*)	1. In situ: • Data: Number of farms, transportation routes, hospitals, movement of population, air travel (Influenza), type of housing 2. Satellite: • Data: PAN, VIS, NIR channels • Information: Urban maps	$I/U_{imp} = 94603 + 61966 + 46486 + 6192 + 5777 + 2951 + 2090 + 1702 + 616 + 1 + 1 + 1 + 1 + 1 + 1 + 1$ $I/U_{imp} = 222390$
Source of Drinking Water (*SDW*)	1. In situ: • Data: (*e.g.,* well locations)	$SDW_{imp} = 61966 + 2951$ $SDW_{imp} = 64917$
Access to Health Care (*AHC*)	1. In situ: **N/A**	$AHC_{imp} = 61966$

Table 15: Ranking of Vector Ecology and Behavior Information

GEO Task US-09-01a: Priority Earth Observations for Health SBA-Infectious Diseases Sub-Area Vector Ecology and Behavior Category		
EO Parameter	**Data – Information - Products**	**Ranking (Cumulative Impact)**
Vector Population (*VP*)	1. In situ: • Data: (*e.g.,* mosquito abundance, density; pig density (Japanese encephalitis), tick population and small mammal distribution (Lyme disease), marsupial population (Ross river virus); dead crow (West Nile Fever))	$VP_{imp} = 94603 + 46486 + 1525 + 709 + 667 + 616 + 1 + 1 + 1 + 1 + 1 + 1 + 1 + 1$ $VP_{imp} = 144615$
Pathogen Population Dynamic (*PPD*)	1. In situ: **N/A**	$PPD_{imp} = 46486 + 1$ $PPD_{imp} = 46487$
Distribution and Density of Susceptible Animal Hosts (*AH*)	1. In situ: • Data: Bird migration, poultry movement (avian flu); elk population size and elk feeding data (Brucella), snail survey (Fasciolosis), Distribution and prevalence of deer mice (Hantavirus), snail distribution (Shistosomiasis); presence of rodents, felines for (Toxoplasmosis)	$AH_{imp} = 1702 + 1 + 1 + 1 + 1 + 1$ $AH_{imp} = 1707$

N/A = not available

6 Additional Findings

6.1 Towards More Integration between Epidemiology and EO

From the literature review and discussions with experts, we found that the operational use of EO for human health is not yet as advanced as for other SBAs (*e.g.*, food security) although the potential is great. Documents describing operational applications are less numerous than research papers describing the potential of using EO observations. We found examples where real-time observations improved assessment of climate-sensitive disease risk, allowed more timely interventions, and also provided the initial and boundary conditions needed for reliable short- and long-range forecasts. For example, in Ethiopia and Eritrea, rainfall and temperature data are used routinely to estimate malaria risk (Grover-Kopec et *al.*, 2006; Ceccato *et al.*, 2007; Connor *et al.*, 2008).

Although at least eight African countries are developing malaria early warning systems (WHO, 2005), there is still a huge potential to improve health warning systems and the integration of EO parameters in the decision-making process. As suggested by Kuhn *et al.* (2004) and the Committee on the Earth System Science for Decision about Human Welfare (2006), this would require:

- Widespread introduction of GIS tools that increase the accessibility of surveillance data and integration of EO information
- Maintain and strengthen diseases surveillance systems
- Integrate spatial data on environmental conditions with socioeconomic data
- Acquire, archive, and access long-term environmental and epidemiological data
- Develop methods to assess the predictive accuracy of the systems
- Include health policy makers in all stages of system design and implementation
- Develop capacity and train decision-makers to analyze and interpret the data, information, and products derived from EO in conjunction with epidemiological data.

Nevertheless, we noticed that the number of publications (peer-reviewed reports) relating epidemiology and EO parameters has increased during the last few

years (Figure 4). This suggests increasing interest in both the disciplines and products/tools that integrate epidemiology and EO. New operational products

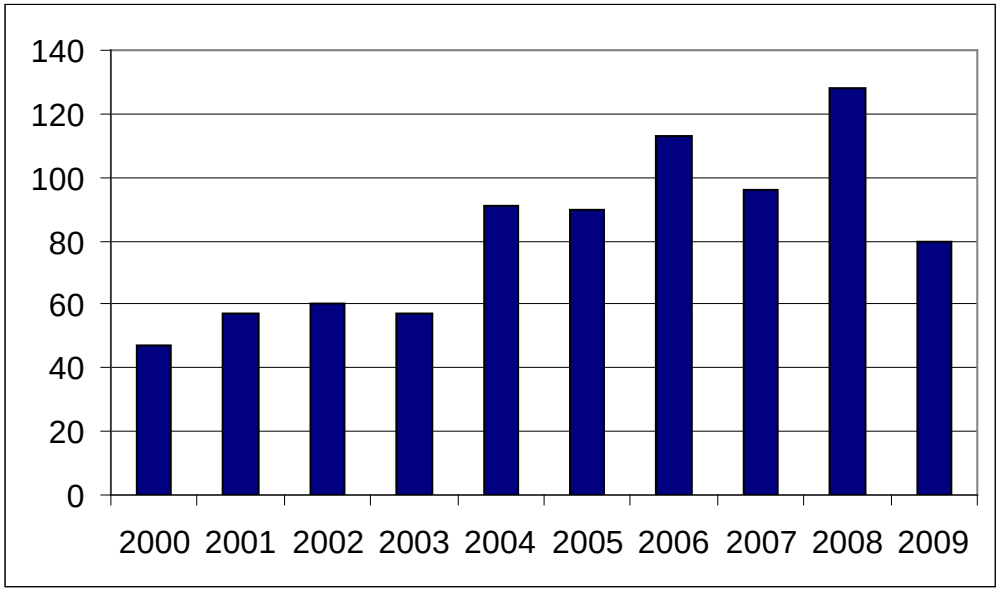

Figure 4: Number of Documents per Year using EO in Epidemiology

and tools (such as the IRI MapRoom, RedGems, NASA-SERVIR [see Table 16] and the soon-to-be-released WHO Open Health) will provide the opportunity to more effectively integrate epidemiology and EO parameters.

Table 16: Examples of Operational Products

Organization	Decision-Support Systems	Location
1. IRI, Columbia University	IRI Health Map Room	http://iridl.ldeo.columbia.edu/maproom/.Health/
2. CNES	RedGems	http://www.redgems.org/
3. NASA	SERVIR	http://www.nasa.gov/mission_pages/servir/index.html
4. ISID	Pro-MED program	http://www.promedmail.org/pls/otn/f?p=2400:1000:
5. USAID FEWS NET	ADDS	http://earlywarning.usgs.gov/adds/

6.2 Gaps

During the investigation of the literature and discussions with experts and AG members, we also identified a series of gaps in i) data, ii) data delivery, and iii) in

development and feedback mechanisms for integrating epidemiology and EO as follows:

6.2.1 Gaps in Data

1. Direct measurement of EO and epidemiological are not always available
2. Some essential information is often lacking (*i.e.,* understanding the host behavior, its relationship with the habitat and its adaptation to new conditions)
3. Neither health data nor EO are always freely available for a variety of reasons, including explicit individual government rules that regulate the exchange of these data
4. Lack of standards in data and products
5. Lack of validation of certain EO products (*e.g.,* derived products from remotely sensed data are not always validated with ground-truth)
6. Lack of quality control related to observations: emphasis should be placed on access to authoritative data that are data which meet approved standards for accuracy and reliability
7. Lack of in-situ measurements for monitoring specific variables (*e.g.,* pH for marine ecosystems)
8. Confusion between product versus data – need to avoid confusion by separating basic parameters from derived parameters

6.2.2 Gaps in Data Delivery

1. Decision-makers need information-products, not data
2. Need to customize the data and products to the decision-makers' needs
3. The products must be easily accessible and free of charge or available at low cost
4. Need to develop tools for integration of epidemiological and EO data
5. Mismatches between spatial and temporal scale of EO and scale at which decisions are made can limit utility of data and information products
6. Difficulty in characterizing uncertainty in forecasts derived from EO data can impede use of information products for decision making

6.2.3 Gaps in Development and Feedback Mechanisms for Integrating Epidemiology and EO

1. Lack of a specific discipline integrating climate-environment-epidemiology (*e.g*., agro-climatology for agriculture discipline) which could help developing new tools and analytical methods
2. Need for better interaction between the scientific community and decision-makers through the boundary institutions as noted in the 10-Year Implementation Plan Reference Document produced by GEOSS in 2005

and the white paper Health and Climate – Needs discussed at the WCC3 in September 2009

3. Need for better approaches that combine EO parameters with social data on exposure and vulnerability at scales that are relevant for the decision makers
4. Lack of feedback mechanisms between research communities and decision-makers
5. Limited number of institutions which serve as transferring research into operation
6. Lack of training and capacity building to provide the means to understand data and product requirements expressed by each of the three categories of users
7. The institutional capacity to work across epidemiological and environmental fields is often missing. This can be addressed by creating new organizations between the existing health and climate institutions. One successful approach is creation of "Climate and Health Working Groups" between the ministries of health and national meteorological services. This has been pioneered in Ethiopia (Ghebreyesus *et al.* 2008) and is being developed by Kenya, Madagascar, and several West African countries.

6.3 Use of EO in Support of Health Care Delivery

In addition to the identified relationships between EO and infectious diseases, EO and forecasts are also of value in supporting health interventions, particularly where weather information can be used to support efforts to deliver health care to remote places or in providing general guidance that can lead to effective planning including staffing and the forward deployment of vaccines, medicines, and medical supplies.

7 Analysts' Comments and Recommendations

7.1 Process and Methodology

Advisory Group:

Use of the Advisory Group was extremely helpful to guide the Analyst and identify source material. The workshop organized in Geneva helped greatly to identify at an early stage of the analysis the objectives and analytical methods. During the workshop, we were able to:

- Identify priority user needs
- Identify and answer the key research questions:
    - Who are the data users?
    - What data do they currently use?
    - How do they use these data?
    - What type of data do they need to do their work better?
- Develop the analytical methods and priority-setting criteria
- Identify informative literature sources
- Identify gaps

Analysis of Documents:

Due to the many different diseases investigated, a large number of documents were gathered to identify the EO parameters. We found that the best method to extract relevant information and subsequently analyze the data was to create a database in Access which allowed us to query the data according to different criteria (*i.e.,* number of publications per region or per diseases, EO parameters per disease, year of publications). The flexibility of the research engine allowed us to quickly analyze the information entered in the Access database. The database is accessible via: http://iri.columbia.edu/~pceccato/GEO-Human-Health-SBA-Access-database/.

Report Outline:

The common template and detailed outline provided by the UIC was greatly appreciated. It helped the process of compiling the report.

7.2 Challenges

The challenges were to gather, analyze, and extract relevant information from many documents in a short period of time. Our analysis started in June 2009. However, the development of the Access database and Endnote file helped us to quickly analyze different sources of information from different regions in the world. The help from Gino Chen, Gilma Mantilla, and Catherine Green in collecting the literature in Chinese, Spanish-Portuguese, and English was greatly appreciated.

7.3 Recommendations

The report identified i) the EO parameters (derived from in situ, satellite, and models) that are of importance to monitor and forecast outbreaks of 44 diseases and ii) several areas where GEO could intervene to improve the uptake of environmental information by the heath sector. In particular:

- While there are many environmentally sensitive diseases and indications that the use of weather and climate information could impact health decisions, the uptake of environmental information by the health sector is limited. In part, this is due to the lack of understanding of the potential of this information to effectively improve health outcomes within the health sector. It is recommended that the GEO community take a more proactive approach to promote opportunities for environmental education and training within the health sector.

- Most GEO health-related activities either fall short of including health practitioners in projects, or where there is a strong health presence, the GEO observing community is often absent. It is recommended that GEO focus on end-to-end projects and that these projects be developed jointly by the GEO environmental community and health practitioners to demonstrate the value of weather and climate information to the health sector.

- A common framework for the exchange and integration of environmental, social, and epidemiological information is needed. While attempts are being made to standardize data formats, there is no formal mechanism to ensure the interoperability of epidemiological, social, and environmental data. It is recommended that GEO provide environmental information in a form that can be readily assimilated by health information systems and accessible by common GIS tools. It is particularly important to ensure that the environmental data are available on the appropriate space and time scales to enable integration with social, economic, and health data.

- All data have associated costs, which must often be borne by the user of the data. It is recommended that GEO work with its members and

cooperating organizations to help in minimizing the cost of data, especially where the application of the information is for humanitarian needs, such as health care.

- It is recommended that this report and its companion reports and documents be made widely available to health practitioners through the World Health Organization and other avenues.

- Currently there is no well-defined mechanism for the exchange of information between the health sector and the environmental community. It is recommended that GEO focus on strengthening boundary institutions that engage both the health and environmental communities, and build on current efforts to improve cooperation between GEO member institutions and the health sector.

Appendix A: Acronyms

ADDS	Africa Data Dissemination Service
AERONET	AErosol RObotic NETwork
AFRO	Regional Office for Africa
AFSSA	Agence Française de Sécurité Sanitaire des Aliments
AFSSET	Agence Française de Sécurité Sanitaire de l'Environnement et du Travail
AG	Advisory Group
ALOS	Advanced Land Observing Satellite
AMSR-E	Advanced Microwave Scanning Radiometer – Earth Observing System
AVHRR	Advanced Very High Resolution Radiometer
AVNIR-2	Advanced Visible and Near Infrared Radiometer
CCD	Cold Cloud Duration
CDC	Centers for Disease Control
CHAART	Center for Health Applications of Aerospace Related Technologies
CIESIN	Center for International Earth Science Information Network
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement/French Agricultural Research Centre for International Development
CMAP	NOAA CPC Merged Analysis of Precipitation
CMORPH	NOAA CPC Morphing Technique
CNES	Centre National d'Etudes Spatiales
CPC	Climate Prediction Center
CREST	Cooperative Remote Sensing Science & Technology Center
CSE	Centre de Suivi Ecologique
CSUMB	California State University Monterey Bay
DALY	Disability-adjusted life year
DAYMET	Daily Surface Weather and Climatological Summaries
ECMWF	European Centre for Med-Range Weather Forecasts
ENSO	El Niño-Southern Oscillation
EO	Earth Observations
EPA	Environmental Protection Agency
ERG	Eastern Research Group
ESA	European Space Agency
ETM	Enhanced Thematic Mapper
EVI	Enhanced Vegetation Index
FEWS NET	Famine Early Warning System Network
FIOCRUZ	Fundação Oswaldo Cruz
GCM	General Circulation Models
GEMI	Global Environmental Monitoring Index
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems

GIS	Geographical Information System
GMS	Geosynchronous Meteorological Satellite
GOES	Geostationary Operational Environment Satellite
GOMS	Geostationary Operational Meteorological Satellite
GPCP	Global Precipitation Climatology Project
GVI	Global Vegetation Index
HCF	Health and Climate Foundation
HIV-AIDS	Human Immunodeficiency Virus – Acquired Immune Deficiency Syndrome
HyspIRI	Hyperspectral Infrared Imager
IFRC	International Federation of Red Cross and Red Crescent Societies
INRA	French National Institute for Agricultural Research
INSAT	Indian National Satellite System
INSERM	Institut National de la Santé et de la Recherche Médicale
IOI	Indian Oscillation Index
IR	Infrared
IRD	Institut de Recherche pour le Développement
IRI	International Research Institute for Climate and Society
ISID	International Society for Infectious Diseases
JHBSPH	Johns Hopkins Bloomberg School of Public Health
JRC	Joint Research Center
LAI	Leaf Area Index
LDCM	Landsat Data Continuity Mission
LPRM	Land Parameter Retrieval Model
LST	Land Surface Temperature
MARA	Mapping Malaria Risk in Africa
MARC	Mosquito and Arbovirus Research Committee (Australia)
MIR	Middle Infrared
MISR	Multiangle Imaging SpectroRadiometer
MODIS	Moderate Resolution Imaging Spectroradiometer
MSAVI	Modified Soil-Adjusted Vegetation Index
MSPH	Mailman School of Public Health
MSS	Multispectral Scanner
N/A	Not available
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NDBC	National Data Buoy Center
NDPI	Normalized Difference Pond Index
NDTI	Normalized Difference Turbidity Index
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NGO	Non-Governmental Organization
NIR	Near-Infrared
NMHS	National Meteorological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration

NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NRC	National Research Council
ONI	Oscillation Niño Index
PAHO	Pan American Health Organization
PAN	Panchromatic
PDO	Pacific Decadal Oscillation
PM	Passive Microwave
ProMED	Program for Monitoring Emerging Diseases
RBM	Roll Back Malaria
RCMRD	Regional Center for Mapping of Resources for Development
RedGems	Re-Emergent Diseases Global Environment Monitoring from Space
RFE	NOAA CPC Africa Rainfall Estimates
RS	Remote Sensing
SAR	Synthetic Aperture Radar
SARS	Severe Acute Respiratory Syndrome
SAVI	Soil Adjusted Vegetation Index
SBA	Societal Benefit Area
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SEDAC	Socioeconomic Data and Applications Center
SMAP	Soil Moisture Active & Passive
SOI	Southern Oscillation Index
SPOT	Satellite Pour l'Observation de la Terre
SRTM	Shuttle Radar Topography Mission
SSH	Sea Surface Height
SSMI	Special Sensor Microwave Imager
SST	Sea Surface Temperature
TIR	Thermal Infrared
TM	Thematic Mapper
Tmax	Maximum Air Temperature
Tmean	Mean Air Temperature
Tmin	Minimum Air Temperature
TOMS	Total Ozone Mapping Spectrometer
TREES	Tropical Ecosystem Environment Observation by Satellites
TRMM	Tropical Rainfall Measuring Mission
UIC	User Interface Committee
UN	United Nations
UNDP	United Nations Development Programme
UN FAO	United Nations Food and Agriculture Organization
UN WHO	United Nations World Health Organization
UN WMO	United Nations World Meteorological Organization
USAID	United States Agency for International Development
USGS	United States Geological Survey
VS	Visible
WCC3	World Climate Conference 3

ZPOM Zone Potentially Occupied by Mosquito

Appendix B: Classification of Pathogen Agents

Table 17: Virus, Bacteria, and Parasites Taxonomy[4]

	Pathogen Agent			Disease
	Family	**Genus**	**Species**	**Name**
RNA Virus	*Arenaviridae*	*Arenavirus*	*Lassa virus*	Lassa fever
			Junin virus	Argentine hemorrhagic fever
			Machupo virus	Bolivian hemorrhagic fever
			Guanarito virus	Venezuelan hemorrhagic fever
			Sabia	Brazilian hemorrhagic fever
	Bunyaviridae	*Orthobunyavirus*	*Bunyamwera virus*	Hemorragic fever
		Hantavirus	*Hantaan, Dobrava-Belgrade, Seoul, Puumala viruses*	Hemorragic fever with renal syndrome
			Sin nombre virus	Hanta virus pulmonary syndrome
		Nairovirus	*Crimean-Congo hemorrhagic fever virus*	Crimean-Congo hemorragic fever
		Phlebovirus	*Rift Valley fever virus*	Rift valley fever
	Filoviridae	*Ebola-like virus*	*Ebola virus, etc.*	Ebola fever
		Marburgvirus	*Lake Victoria Marburgvirus, etc.*	Marburg fever
	Flaviviridae	*Flavivirus*	*Dengue virus*	Dengue fever
			Yellow fever virus	Yellow fever
			Japanese encephalitis virus	Japanese encephalitis
			West Nile virus	West Nile fever, Kunjin virus fever
			Murray valley encephalitis virus	Murray valley encephalitis
			Saint Louis encephalitis virus	Saint Louis encephalitis
	Orthomyxoviridae	*Influenzavirus*	*Influenza A virus*	Influenza flu (Avian, Human, pigs, horses, etc.)
			Influenza B virus	Human Influenza flu
			Influenza C virus	Human Influenza flu

[4] Sources: i) Rodhain and Perez, 1985; ii) Pilly, 2009; iii) Sayers *et al.*, 2009; iv) Benson *et al.*, 2009

	Paramyxoviridae	*Henipavirus*	*Hendra virus*	Neurological syndrome
			Nipah virus	Encephalitis and/or pulmonary syndrome
	Reoviridae	*Orbivirus*	*Bluetongue virus 1, etc.*	Blue tongue
		Rotavirus	*Human rotavirus*	Severe diarrheal disease
	Retroviridae	*Lentivirus*	*Human immunodeficiency virus*	Acquired immunodeficiency syndrome (AIDS)
		Deltavirus	*Primate T-lymphotropic virus 1*	Human T cell Leukemia/lymphoma Virus (HTLV)
	Togaviridae	*Alphavirus*	*Barmah forest virus*	Epidemic polyarthritis, rash and fever
			Chikungunya virus	
			Ross River virus	

	Pathogen Agent			**Disease**
	Family	**Genus**	**Species**	**Name**
Bacteria	*Brucellaceae*	*Brucella*	*Brucella melitensis, B. suis, B. abortus, B. canis*	Brucellosis
	Chlamydiaceae	*Chlamydia*	*Chlamydia trachomatis*	Trachoma
	Enterobacteriaceae	*Salmonella*	*Salmonella enterica*	Salmonellosis
		Shigella	*Shigella flexneri, S. dysenteriae, S. boydii, S. sonnei*	Shigellosis
		Yersinia	*Yersinia pestis*	Plague
	Leptospiraceae	*Leptospira*	*Leptospira sp.*	Leptospirosis
	Neisseriaceae	*Neisseria*	*Neisseria meningitidis*	Meningitis
	Spirochaetaceae	*Borrelia*	*Borrelia burgdorferi*	Lyme disease
			Borrelia recurrentis	Relapsing fever
			Borrelia duttonii, B. hispanica, B. parkeri, B. venezuelensis, etc.	Regional relapsing fever
	Vibrionaceae	*Vibrio*	*Vibrio cholerae*	Cholera
	Sarcocystidae	*Toxoplasma*	*Toxoplasma gondii*	Toxoplasmosis

	Pathogen Agent			Disease
	Family	**Genus**	**Species**	**Name**
Parasites	*Ancylostomatidae*	*Ancylostoma*	*Ancylostoma duodenale*	Ankylostomiasis (hookworms)
		Necator	*Necator americanus*	
	Ascarididae	*Ascaris*	*Ascaris lumbricoides*	Common roundworm
	Dracunculidae	*Dracunculus*	*Dracunculus medinensis*	Dracunculosis (Guinea worm)
	Entamoebidae	*Entamoeba*	*Entamoeba histolytica*	Amibiasis
	Fasciolidae	*Fasciola*	*Fasciola hepatica*	Fasciolosis (Liver fluke)
	Plasmodiidae	*Plasmodium*	*Plasmodium falciparum*	Malaria
			Plasmodium malariae	
			Plasmodium ovale	
			Plasmodium vivax	
	Onchocercidae	*Onchocerca*	*Onchocerca volvulus*	Onchocercosis
		Wuchereria	*Wuchereria bancrofti*	Lymphatic filariosis
		Loa	*Loa loa*	Loaloa filariasis (African eye worm)
	Trypanosomatidae	*Leishmania*	*Leishmania chagasi*	Leishmaniosis
			Leishmania donovani	
			Leishmania infantum	
			Leishmania major	
		Trypanosoma	*Trypanosoma cruzi*	Chagas disease
			Trypanosoma brucei	African trypanosomiasis
	Schistosomatidae	*Schistosoma*	*Schistosoma haematobium*	Schistosomiasis
			Schistosoma mansoni	
			Schistosoma intercalatum	
			Schistosoma japonicum	

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Appendix D: Input to the Cross-SBA Analysis

At the conclusion of the individual SBA priority-setting analysis, the Health SBA-Infectious Diseases Analyst provided input on the overall critical Earth observation parameters for the Infectious Diseases sub-area for inclusion in the Cross-SBA meta-analysis.[5] Upon receiving input from the SBA Analysts, the Cross-SBA Analyst reviewed the priorities in order to harmonize the terminology employed across SBAs. The Cross-SBA Analyst aggregated observation parameters that are the same or very similar but have different names (e.g., precipitation intensity and precipitation duration). In some cases, the Cross-SBA Analyst also disaggregated observation parameters from observation categories that were identified as priorities by individual SBAs. As a result, the number of observation priorities identified by individual SBAs may vary from the number of observations that were included in the Cross-SBA analysis. To the extent possible, the Cross-SBA Analyst focused on retaining the observation parameter terminology employed by the majority of the SBAs.

Three separate sub-reports (Air Quality, Infectious Diseases, and Aeroallergens) were prepared by separate Analysts for the Health SBA. The results of these sub-reports were merged and treated as a single SBA report for the purposes of the Cross-SBA analysis. The Health SBA-Infectious Diseases Analyst determined the overall critical Earth observation priorities for the Infectious Diseases sub-area based on the burden of the diseases, measured by the cumulative disability-adjusted life year (DALY), as described in Sections 2.3.3 and Chapter 5. Based on the results of the prioritization analysis, the 27 observations listed below have the highest rankings and thus are considered to be the observation priorities for the Health SBA-Infectious Diseases sub-area. Accounting for differences in observation terminology across the SBAs, the Health SBA-Infectious Diseases Team effectively contributed 25 observation parameters to the Health SBA input for Methods 1-3 of the Cross-SBA analysis. The Infectious Diseases Analyst divided the 27 observations into the three tiers representing “High,” “Medium,” and “Low” priority observations for numerical weighing in Cross-SBA Methods 2 and 3. (Italicized observations were also included in Method 4, as explained below). The below-listed 27 observations were included as part of the single integrated list of Health SBA priorities for Methods 1-3 of the Cross-SBA Analysis.

High
Population Density
Precipitation
Infrastructure/Urbanization
Temperature
Humidity
Land Use
Vegetation

[5] For full description of methods and results, refer to: Group on Earth Observations. Task US-09-01a. Critical Earth Observation Priorities. Final Report. October 2010. Available on GEO Task US-09-01a website: http://sbageotask.larc.nasa.gov/.

Water Bodies
Sea Surface Temperature

Medium
Wind
Sea Surface Height
Topography
Vector Population
Dust
Biodiversity
Source of Drinking Water
pH
Salinity

Low
Access to Health Care
Algal Blooms
Forest Cover
Pathogen Population Dynamic
Soil Type
Density of Animal Host
Soil Moisture
Deforestation
Sunshine Radiation

The list of 49 observations, provided below, is the union of the three Health SBA sub-reports' priority lists. This list was used for Method 1 (unweighted tally of observations) and Methods 2 and 3 (weighted tally of observations) in the Cross-SBA analysis. For Methods 2 and 3, the rankings of "High," "Medium," and "Low" were determined based on the highest rank assigned to an observation parameter across the 3 Health SBA Analysts.

Ambient Nitrogen Dioxide Concentration
Ambient Ozone Concentration
Ambient Particulate Matter (fine) Composition
Ambient Particulate Matter Composition (coarse)
Ambient Particulate Matter Concentration (coarse)
Ambient Particulate Matter Concentration (fine)
Ambient Sulfur Dioxide Concentration
Ambient Volatile Organic Compounds
Biodiversity
Column Nitrogen Dioxide Concentration
Column Ozone Concentration
Column Particulate Matter Concentration (coarse)
Column Particulate Matter Concentration (fine)
Column Sulfur Dioxide Concentration
Deforestation
Density of animal hosts
Elevation
Field Cover (Continuous)
Forest Cover
Glacier/Ice Sheet Extent
Global Horizontal Irradiation (GHI)

Gross Primary Productivity
Health Care Access
Land Cover
Land Use
Leaf Area Index
NDVI
Ocean Topography
Pathogen Population Dynamic
Phenology
Photosynthetically Active Radiation (PAR)
Population
Precipitation
Sea Level
Sea Surface Temperature (SST)
Soil Moisture
Soil Type
Source of Drinking Water
Surface Air Temperature
Surface Humidity
Surface Wind Direction
Surface Wind Speed
Urbanization
Vector Population
Vegetation Cover
Vegetation Type
Water Algal blooms
Water Bodies (location)
Water Quality & Composition, pH and salinity, Dissolved Oxygen Content

For Method 4, the "15 Most Critical" observation list for the Health SBA was prepared collectively by the Health Analysts and Cross-SBA Analyst based on the commonality across the 3 sub-reports' "Most Critical" observation lists. The "15 Most Critical" observations for the Health SBA are listed below. The Health SBA-Infectious Diseases sub-report contributed the italicized priority observations (listed above under "High" and "Medium") to this list.

1. Population Density
2. Precipitation
3. Air temperature
4. Humidity
5. Land Use/Land Cover
6. Vegetation
7. Water Bodies
8. Sea Surface Temperature
9. Wind
10. Sea Surface Height
11. Topography
12. Vector population
13. Atmospheric Particulates
14. Biodiversity
15. Atmospheric trace gases