

Identification of Earth Observation data for health-environment studies

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Abstract - The availability and accessibility of an increasing amount of Earth Observation (EO) data enable the investigation of links between health effects and environmental conditions. A main challenge is the identification of suitable EO data according to the requirements for environmental information defined by health experts. The EO2HEAVEN project focuses on the development of an early alert system for air quality issues and cholera outbreaks. Under that frame, researchers and health experts identified 16 environmental parameters that may affect human health. These parameters concern weather and climate (air temperature, humidity and pressure, precipitation, wind), air quality (NO₂, O₃ and SO₂ concentration, particulate matter), land (vegetation activity, land use, topography) and water (sea surface temperature, height and salinity, chlorophyll-a concentration). In this paper, we identify and comment on potentially suitable EO data for health applications. Whenever available, we prioritized the use of data registered as GEOSS resources.

Keywords: Air Quality, Aquatic systems, Health, Earth Observation

1. INTRODUCTION

Spatial epidemiology is the study of spatial variation in disease risk or incidence (Ostfeld et al., 2005). This research area has drastically evolved in the last decade to assess health risks associated with environmental hazards (Beale et al., 2008). However, the development of spatial epidemiological studies is limited by the availability, accessibility and quality of relevant data on population, health outcomes and environmental conditions (Beale et al., 2008). With regards to Earth Observation (EO) data, the release of new remote sensing data is expected to carry strong improvements in health-environment researches (Beck et al., 2000). The launch of the Global Earth Observation System of Systems (GEOSS) project in 2005 enables the increased availability and accessibility of environmental information for the investigation of potential links between health effects, diseases and environmental conditions at different locations and time periods. GEOSS recognizes Health as one of the nine identified Societal Benefit Areas (SBA). One of the objectives of GEOSS is to use remote sensing observations of weather, land and ocean parameters to predict outbreaks or trends in infectious diseases such as meningitis, malaria and cholera. The 10-year implementation plan of the Health theme focuses on making the relevant EO data readily available to public health workers in a format that they can use (http://www.earthobservations.org/geoss_he.shtml).

The objective of this paper is to provide a short (but incomplete) review of available EO data and briefly comment on their

relevancy for health-environment applications. Efforts are made to include resources made available to GEOSS. Validation results for each available EO data are not included because it would be inappropriate. This is due to the fact that requirements on EO data quality vary, depending on the health risks analysed.

2. STUDY FRAMEWORK

This research has been produced under the frame of the EO2HEAVEN (Earth Observation and Environmental Modelling for the mitigation of Health risks) FP7 project, which aims at contributing to a better understanding of the complex relationships between environmental changes and their impacts on human health (www.eo2heaven.org). Three case studies have been defined regarding air quality-related diseases in Saxony state (Germany) and Durban (South Africa) and water-borne diseases (cholera outbreaks in Uganda). For each of these case studies, health experts were asked to list the environmental parameters that may affect health risks. As a result, a list of 16 environmental parameters was produced, regarding climate and weather, atmospheric composition, land and water parameters. Even if this list is not exhaustive as it was only based on three well identified case studies, we consider that most of the environmental parameters identified may be of interest for other health-environment studies, such as studies linked to vector-borne diseases for instance.

3. CLIMATIC AND WEATHER PARAMETERS

Climate and health conditions are highly connected. These connections may be considered as direct or indirect connections. For instance, intense floods can kill people but can also affect health by favouring the appearance of water-borne diseases. Moreover, one may distinguish between climate and weather relationships with health. Climate constrains the range of many infectious diseases, and weather affects the timing and intensity of outbreaks (Epstein, 1999). As a consequence, impacts of climate change on health conditions are expected to be severe. Actually, there is already major evidence that climate change may be affecting human health including mortality from heat, cold, or climate disasters; changes in air and water quality; and changes in the ecology of infectious diseases (Sunyer and Grimalt, 2006). As a consequence from the increasing interest in climate change and weather conditions, many Earth Observation programs have been developed to improve the monitoring of climate and weather, which both are now considered as Societal Benefit Areas in GEOSS. Rainfall and air temperature are the most commonly considered climatic parameters that have potential effects on human health. However, other variables such as air pressure, air humidity and winds should not be excluded.

Rainfall is one of the most complicated parameters to be mapped due to its high temporal and spatial variability, especially in tropical areas where rainfall is mostly due to convection systems. Here, we identified three products that may be of interest for health-environment studies: the TRMM 3B42, RFE2.0 and GPCP products. All of these products are actually merged products based on remote sensing and in-situ data. After comparisons with in-situ raingauge measurements, we observed that RFE2.0 (based on METEOSAT data) data were slightly more accurate than TRMM (3B42 product) data in South Africa and Uganda. However, both datasets were not accurate enough to be used at a daily time scale, but only at a weekly or even monthly resolution. The spatial resolution of the GPCP dataset is a strong limitation for using it in health-environment studies. As a consequence, in-situ data may be preferred in developed countries where raingauges networks are usually quite dense.

Air temperature, air humidity and air pressure are often provided as different data fields in common EO products, as those from AIRS, MODIS or IASI. These parameters are commonly released as atmospheric profiles so that, in the context of health studies, the user can extract information from the near surface layer. All products present a relevant temporal resolution for health applications as it may allow detecting extreme hot or cold events. However, the coarse spatial resolution may be a limiting factor for local scale studies (for example, the urban heat island effect can only be observed in very large cities).

Measuring wind speed and direction from using remote sensing is a complex task. Techniques based on active and passive sensors have been developed but it only works over ocean surfaces (the principle is based on the study of sea surface roughness and its relationship with winds). As a consequence, its application to health studies is restricted to water-borne diseases (for instance, to anticipate the dispersion of phytoplankton blooms) and coastal areas. Other interesting data regards the GLDAS (Global Land Data assimilation System) which proposes 3 hourly data of wind measurements over land issued from the NOAA model.

4. AIR QUALITY PARAMETERS

Air pollution has been recognized for a long time as a major health issue. Scientific studies show that personal exposure to air pollution may shorten life expectancy, through favouring the appearance of lung cancer, cardiovascular diseases, respiratory or asthma symptoms (Brunekreef and Holgate, 2002). Amongst major air pollutants considered for their health effects, special attention is given to ozone (O₃), nitrogen dioxide (NO₂) and

particulate matter. Regarding particulate matter, a distinction is made between PM₁₀ (particles smaller than 10 µm), PM_{2.5} (particles smaller than 2.5 µm) and ultrafine particles (particles smaller than 100 nm), due to their different effects on health (Brunekreef and Holgate, 2002). Sulphur dioxide (SO₂) can also be added to this list of air pollutants. Although its global atmospheric concentration has decreased in the second half of the twentieth century, the local concentrations of SO₂ over industrial cities such as Dresden (Saxony, Germany) and Durban in South Africa are still of concern.

Various sensors were launched in the past decade in order to observe trace gases (e.g. NO₂, SO₂ and O₃) and aerosols (which are considered as an indicator of particulate matter concentration). A complete review on the use of remote sensing for mapping surface air quality has been proposed by Martin (2008). This author highlights main issues for mapping air pollution from remote sensing images. One major issue refers to the requirement of concentrations of air pollutants at ground level for exposure and dose-response models. Indeed, while the sensor observes the trace gases in the entire atmosphere, health applications only require concentration values of the air pollutants at the boundary layer. For NO₂ and SO₂, it is considered that the most part (around 2/3) of the tropospheric NO₂ and SO₂ columns is concentrated in the boundary layer, near the pollution sources. It means that these values can be considered as a proxy for NO₂ and SO₂ concentration. Thus, NO₂ and SO₂ tropospheric column estimates from sensors such as OMI, SCIAMACHY or GOME-2 should be relevant for health applications. Regarding ozone concentration, the boundary layer constitutes only a small fraction of the total O₃ column (Martin, 2008). It is then necessary to get access to the vertical profiles of ozone concentrations, in order to extract only the boundary layer. This is possible when using SCIAMACHY or OMI products. Aerosol optical properties can be analysed to get information on aerosols size distribution, shape and composition that can then be related to particulate matter concentration. For instance, the MOD07 level 2 product from MODIS seems particularly adequate for this purpose. A second issue highlighted by Martin (2008) regards the validation of satellite air quality retrievals. The spatial and temporal resolutions of in-situ measurements limit the interest of comparison of in-situ data with remote sensing estimates. Moreover, the units of gas concentrations measured by in-situ and remote sensors are different (µg.m⁻³ and mol.cm⁻², respectively). This may turn into a major issue if one wants to compare values with maximum concentration values allowed by air quality guidelines and standards. Finally, it has to be considered that the coarse spatial resolution of the remote sensing products does not allow leading intra-urban studies (Martin, 2008).

Table 1. List of relevant environmental parameters and corresponding EO data for health and environmental studies.

Parameter	Main sensor/ Example of Product ID	Begin date	Temporal resolution	Spatial coverage	Spatial resolution	Access	Resource for GEOSS
Rainfall	TRMM 3B42	1998	1 day	Tropics	0.25°	http://mirador.gsfc.nasa.gov/	Yes
	MSG/RFE2.0	2001	1 day	Africa	0.10°	http://www.cpc.ncep.noaa.gov/	No
	/GPCP	1996	1 day	Global	1°	http://www1.ncdc.noaa.gov/	No
Air Temperature	AIRS/AIRX3STD	2002	1 day	Global	1°	http://mirador.gsfc.nasa.gov/	Yes
	IASI/IASND02	2006	daily	Global	25 km	http://www.nsof.class.noaa.gov	Yes
	MODIS/MOD 07	2000	sub-daily	Global	5 km	http://modis-atmos.gsfc.nasa.gov/	No
Air pressure	AIRS/AIRX3STD	2002	1 day	Global	1°	http://mirador.gsfc.nasa.gov/	Yes

Parameter	Main sensor/ Example of Product ID	Begin date	Temporal resolution	Spatial coverage	Spatial resolution	Access	Resource for GEOSS
	IASI/IASND02	2006	daily	Global	25 km	http://www.nsof.class.noaa.gov	Yes
	MODIS/MOD 07	2000	sub-daily	Global	5 km	http://modis-atmos.gsfc.nasa.gov/	No
Air humidity	AIRS/AIRX3STD	2002	1 day	Global	1°	http://mirador.gsfc.nasa.gov/	Yes
	IASI/IASND02	2006	daily	Global	25 km	http://www.nsof.class.noaa.gov	Yes
	MODIS/MOD 07	2000	sub-daily	Global	5 km	http://modis-atmos.gsfc.nasa.gov/	No
Winds	ASCAT/ASCAT12	2008	sub-daily	Global (ocean)	12.5 km	http://www.osi-saf.org/	No
	GLDAS/ GLDAS_NOAH025SUBP_3H	2000	3 hours	Global	0.25°	http://mirador.gsfc.nasa.gov/	Yes
Particulate Matter	OMI/OMAERO	2004	1 day	Global	0.25°	http://mirador.gsfc.nasa.gov/	Yes
	MODIS/MOD04	2000	1 day	Global	10 km	http://modis-atmos.gsfc.nasa.gov/	Yes
NO ₂	OMI/OMNO2G	2004	sub-daily	Global	0.25°	http://mirador.gsfc.nasa.gov/	Yes
	SCIAMACHY/	2002	1 day	Global	30 x 60 km	http://www.temis.nl/	No
	GOME2/	2007	1 day	Global	80 x 40 km	http://www.temis.nl/	Yes
SO ₂	OMI/OMSO2G	2004	1 day	Global	0.25°	http://mirador.gsfc.nasa.gov/	Yes
	SCIAMACHY/	2004	1 day	Global	30 x 60 km	http://www.temis.nl/	No
O ₃	OMI/OMO3PR	2004	sub-daily	Global	13 x 24 km	http://mirador.gsfc.nasa.gov/	Yes
	AIRS/AIR3XSTD	2002	1 day	Global	1°	http://mirador.gsfc.nasa.gov/	Yes
	SCIAMACHY/	2004	1 day	Global	30 x 60 km	http://www.temis.nl/	No
Land-use/cover	Spot Imagery Observation Database	1998	26 days	Global	2.5 m	http://www.spotimage.com/	Yes
	Landsat archive	1972	16 days	Global	30 m	http://edcns17.cr.usgs.gov/EarthExplorer/	Yes
	Landsat/Corine Land Cover	2000	-	Europe	12.5 m	http://image2000.jrc.ec.europa.eu/	Yes
	MERIS/Globcover	2005; 2009	-	Global	300 m	http://ionia1.esrin.esa.int/	Yes
	Urban Atlas	2007- 2008	-	European cities	0.25 ha	via GMES	No
Topography	ASTER GDEM	-	-	Global	30 m	http://www.gdem.aster.ersdac.or.jp	Yes
	SRTM	-	-	Global	90 m	http://iceds.ge.ucl.ac.uk/	Yes
	SPOT DEM	-	-	Global	30 m	http://www.spotimage.com/	Yes
Vegetation	MODIS/MOD13Q1	2000	16 days	Global	250 m	https://lpdaac.usgs.gov/	No
	SPOT VEGETATION	1998	10 days	Global	1 km	via GMES	No
SST	MODIS/ MODIS_AQUA_L3_MAPPE D_SST4	2000	1 day	Global	1 km	http://oceancolor.gsfc.nasa.gov/	Yes
	AATSR/ DAP_MG3_04	2008	1 day	Global	1 km	via GMES	No
CHL	MODIS/ L3m_DAY_CHL_chlor_a_4k m	2000	1 day	Global	1 km	http://oceancolor.gsfc.nasa.gov/	Yes
	MERIS/ L3b_GLOB_4_AV- MER_CHL2_DAY	2002	1 day	Global	1 km	http://oceancolor.gsfc.nasa.gov/	Yes
	SeaWiFS/ L3m_DAY_CHL_chlor_a_9k m	1997	1 day	Global	1.1 km	http://oceancolor.gsfc.nasa.gov/	Yes
SSH	JASON-1, JASON-2, TOPEX/POSEIDON/ SEALEVEL_GLO_SLA_L3_ NRT_OBSERVATIONS_008_001	1992	1 day	Global	7 km	Myocean	No

5. LAND PARAMETERS

Landscape is recognized as a major environmental factor affecting disease propagation. In the context of vector-borne diseases, Lambin et al. (2010) claim that an integrated analysis at the landscape scale allows a better understanding of interactions between changes in ecosystems and climate, land use and human behaviour, and the ecology of vectors and animal hosts of infectious agents. As a consequence, land use and land cover maps represent valuable information to be analysed to understand the factors influencing the spatial distribution of a disease.

Requirements on land use depend largely on the case study. For a case study on cholera outbreaks in Uganda, information on urban land use is important in order to consider population density, sanitary conditions and proximity to different water sources, which may help in detecting vulnerable areas to be considered in exposure models. Special attention should be given to temporally flooded areas. In air pollution studies, the focus should be on detecting road networks, industries and parks for instance. Rural land use is also important to be mapped. For example, temporary ponds, rivers and dams need to be monitored as they can represent a host for the *Vibrio Cholerae* pathogen. Vegetation activity can affect air quality. Indeed, pollen concentration may be higher in rural regions, affecting people suffering from allergic reactions. Finally, topography needs to be taken into account. In the context of air quality studies, topography influences the local weather (winds, temperature, humidity, pressure...), favouring or impeding the dispersion of air pollutants. Regarding the cholera case study, knowledge on local topography is necessary to locate the potentially flooded areas and assess the effect of water runoff on the spatial distribution of the disease.

Land use mapping is certainly the most studied thematic in remote sensing research. It is thus impossible to list all its potentialities in this area. According to the spatial scale, one may consider high resolution data such as SPOT or Landsat images. The very fine resolution of these products, i.e. 2.5 m to 30 m is adapted to urban areas. In certain European cities, 3-D Urban Atlas is currently being released which may be of high relevancy for integration in air quality models. At a coarser spatial scale, CORINE land cover maps from Europe are available with a minimal resolution of 0.25 ha per object. In low population density areas, the GlobCover land cover maps at a 300 m resolution may be interesting. Such information on land cover may then be improved by integrating information on vegetation activity. Time series of vegetation indices (mainly NDVI) can be obtained from SPOT VEGETATION and MODIS sensors at 10 and 16 days resolution, respectively. These products give valuable information on the phenological cycles observed in a defined area. Finally, data on topography is provided by SRTM, ASTER DEM or SPOT DEM products at 90 m, 30 m and 30 m spatial resolutions, respectively.

6. WATER PARAMETERS

Water parameters are particularly important to be mapped in the context of water-borne diseases such as cholera. By analysing environmental signatures associated with cholera epidemics in India and Bangladesh, Constantin de Magny et al. (2008) highlighted the importance of water conditions such as Sea Surface Temperature (SST), Sea Surface Height (SSH), Chlorophyll-a concentration (CHL) and Sea Surface Salinity

(SSS). The ocean remote sensing community has a long experience, and access to ocean data is now well structured through the access to web portals such as OceanColor (for SST and CHL), GlobColour (for CHL), GHRSSST (for SST) or AVISO (for SSH). MODIS, AATSR, MERIS and SeaWiFS sensors are commonly used for observing SST and CHL. However, one should notice that most of these products have been initially developed for open ocean (CASE I waters) and may not achieve same accuracies for turbid waters (CASE II waters). SSH products from merged products based on JASON-1&2 sensors, following the TOPEX/POSEIDON initial mission, allow reaching high SSH accuracies (for instance, expected accuracy for JASON-2 is 2.5 cm). Finally, research on SSS still needs large improvements but new data from SMOS and AQUARIUS missions should help in filling this gap.

7. CONCLUSION

Earth Observation data issued from remote sensing images offers interesting perspectives for health-environment studies, which have now been exploited for more than a decade (Beck et al., 2000). In this paper, we identified a list of relevant EO products for observing 16 environmental parameters potentially connected to health issues. The implementation of new international projects, such as GEOSS, facilitates the access and use of this data. However, most of these products have not been initially created for health applications so that their relevancy for such studies still needs to be validated.

REFERENCES

- L. Beale, J.J. Abellan, S. Hodgson, L. Jarup, "Methodologic issues and approaches to spatial epidemiology", *Environmental Health Perspectives*, vol. 116, no 8, p.p. 1105-1110, 2008.
- L.R. Beck, B.M. Lobitz, B.L. Wood, B.L., "Remote sensing and human health: new sensors and new opportunities", *Emerging Infectious Diseases*, vol. 6, no 3, p.p. 217-227, 2000.
- B. Brunekreef, S.T. Holgate, "Air pollution and health", *The Lancet*, vol. 360, p.p. 1233-1242, 2002.
- P.R. Epstein, "Climate and health", *Science*, vol 285, no 5426, p.p. 347-348, 1999.
- G. Constantin de Magny, R. Murtugudde, M.R.P. Sapiano, et al., "Environmental signatures associated with cholera epidemics", *PNAS*, vol 105, no 46, p.p. 17676-17681, 2008.
- E.F. Lambin, A. Tran, S.O. Vanwambeke, C. Linard, V. Soti, "Pathogenic landscapes: interactions between land, people, disease vectors, and their animal hosts", *International Journal of Health Geographics*, vol 9:54, 2010.
- R.V. Martin, "Satellite remote sensing of surface air quality", *Atmospheric Environment*, vol 42, p.p. 7823-7843, 2008.
- R.S. Ostfeld, G.E. Glass, F. Keesing, "Spatial epidemiology: an emerging (or re-emerging) discipline", *TRENDS in Ecology and Evolution*, vol 20, no 6, p.p. 328-336, 2005.
- J. Sunyer, J. Grimalt, "Global climate change, widening health inequalities, and epidemiology". *International Journal of Epidemiology*, vol 35, p.p. 213-216, 2006.