Relevance of Space Observation Parameters in Human Health Impact Assessment and the Integration of New Emerging Sensor Technologies

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Abstract – Space-images needed for the characterisation of environmentally related diseases are identified. This work provides a new perception for environmental monitoring across time and space and is targeted to furnishing an accurate and harmonised assessment on acute as well chronic health diseases associated environmental exposure.

Space monitoring coupled with emerging connectivity of ground sensor technologies enables new evidence-based priority-setting and planning of preventive measures. With this work are identify mobile terminal communication interfaces with wireless processing capabilities for tracking and collection of data and innovative scalable network architectures with improved real-time reporting and management of ground data in a way that accurate human exposure assessments are carried out.

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1. SPACE MONIRORING FOR HEALTH IMPACT ASSESSMENTS

Certain diseases are closely associated with particular environmental conditions and have a specific seasonal variability that can be linked with the variations of local environmental conditions. According to the list adapted from WHO (Ceccato et. al. 2007) these diseases include: Malaria, Yellow Fever, Meningitis, Dengue, Rift Valley Fever, Cholera, African Trypanosomiasis, Lelshmaniasis, West Nile Virus, Japanese Encephalitis, St Louis Encephalitis, Murray Valley, Ross River Virus, Leptospirosis, Influenza etc.

In addition to these, it should be taken into account that there are also several other respiratory diseases and non-communicable diseases that are also related with environmental as well as occupational exposures. For these it has been already demonstrated that space observation can be an important tool for harmonised monitoring. It can also allow advanced applications through a temporal hazards methodology and identify hazards to specific population groups through a target differentiating approach (Skouloudis et al 2007 and 2009).

The use of remote sensing data for assessing health effects requires specific environmental monitoring parameters which are specific for each of the diseases that are listed above. However, for the purposes of health impact assessments we should address:

1. How big is the area of the environmental causes influencing the health effect?
2. How frequently health consequences are happening due to adverse environmental conditions?
3. What is the percentage of the local population effected, and
4. What are the causes of disease outbreaks when the disease is not induced only from environmental causes?

In answering theses we must consider the acute or chronic nature of the disease and the short/long term of environmental monitoring needed. For associating these diseases in environmental or climatic conditions the parameters which should be monitored are shown at Table 1.

Table1. Environmental parameters for health impacts.

Datasets
Air pressure
Air temperature
Cloud cover/sunshine duration
Rainfall
Wind speed/direction
Relative Humidity
UVR
Sea surface salinity
Sea surface temperature
Chl a
Concentration of air pollutants
Dust and PMx
Land Use
Topography
Vegetation activity

The aforementioned parameters are well known from various types of sensors onboard various satellites. However, until recently such images were utilised only in producing risk maps or for producing early warning systems for decision making processes. Nowadays, it is possible to utilise consistently remote observations for consistently addressing the four aforementioned questions for health. For this purpose we will need to merge the following layers of information systems:

    A. Stationary Anthropogenic activities.
    B. Cofounding land observations
    C. Climatic and weather related data
    D. Pollutant concentrations
    E. Sites of local telematic sensor data and
    F. Reported health cases

The requirements from such merging process are to have:

- Comparable domains with the population group susceptible to environmental stress;
- Available associated environmental input parameters that describe human exposure;
- Data structures in compatible temporal periods;
- Sufficient spatial resolution;
- Data for assessing the severity of the problem and the size of the affected population;
- Low geo-reference error;
- Clear description of uncertainties and assumptions in exposure assessments and transmission pathways;

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- Allow to regenerate the map over a regular reference years for account for main anthropogenic changes on the environment;
- Have a capability of map regeneration before and during outbreaks.

The main restrictions on these requirements are the spatial resolution of these images and the satellite revisit period of several days passing over the same location has caused a weak assessment for the environmental burden of several diseases. For this purpose a network satellites with comparable sensors will be essential in the immediate future.

The intermediate solution before such a network of satellites become available will be the deployment of a low-cost network of in situ or mobile sensors. Ground based telematic networks of such sensors are easily deployed nowadays. They can be part of existing wireless mobile telecommunication networks and are indispensable for relaying environmental monitoring data in high temporal frequencies (a few seconds). Therefore, are of significant importance in disaster monitoring as well as for essential ground verification on the onset of extreme environmental effects.

2. SENSOR TECHNOLOGIES

The use of remote sensing data for assessing health effects requires specific high spatial and temporal resolution which until recently was a formidable problem for existing space technologies. A new perception for integrating Environmental monitoring data with harmonised space observations in order to detect and verify health threats which are attributed to environmental causes. Regrettably, the reporting of spatial resolution is frequently inadequate in reporting environmental causes and health effects at the same scale. This work refers to two new methods for examining environmental and health threats. These are related with atmospheric and water pollution and examine different level of frequency and severity of health impact assessments.

The data sets needed for the fusion of environment and health systems are classified against a unique nine scale pyramid of environmental consequences and against a corresponding nine scale pyramid of health effects. This work also generalises the methodology in way that facilitates new regulatory policies and permits abatement strategies that close to real-time due the utilising of latest generation of remote sensing images with innovative monitoring applications.

This approach paves the way to health impact assessments that cannot be carried out with other conventional approaches, recommends the design for merging information systems for accurately describe chronic and acute represent conditions and reports on health consequences not yet identified. In addition it facilitates a precise representation of human exposure taking into account the randomness of human activities and the accurate representation of environmental stressors at high spatial resolution.

"Effect assessment" has also to take into consideration the fact that both the human and environmental populations consist of individuals – every one of us reacts in a unique way to a challenge or stressor. The key concept is advanced high spatial resolution monitoring of populations susceptible to specific environmental hazards. A wider use of earth observation can assist in facilitating the monitoring and reporting requirements in high resolution for the European Union and promote the development of specific applications with links to the Environment and Health action plan. Such observations also harmonize the reporting and provide a systematic warning of legislative violations in areas which are crucial for population health.

Two new methodologies are proposed within this work, which provide a synthesis of satellite observations, in connection with new technologies for environmental monitoring. These new technologies promote the use of open architectures for information systems that offer new opportunities of exploiting the consequences of environment on population health.

3. INTEGRATED APPLICATIONS

Epidemiological statistics incorporate uncertainties due to difficulties of associating the health effects in population groups that are sensitive to specific environmental threats. Such threats could be to children or elderly persons who, due to age and physical restrictions, are exposed to air concentrations in the vicinity of main roads or areas with intensive industrial activities.

The differentiating methodology incorporated below utilises state-of-art information from remote sensing and monitoring tools which are already deployed in order to draw conclusions and generalise, without the uncertainties introduced by classical epidemiological studies and without huge costs that such campaigns might entail for repletion in usual temporal intervals. The methodology used consists of the following steps:

1. Generate or obtain population density maps with spatial resolution of less than $1x1km^2$.
2. Based on local age-pyramid data (country or regional basis) calculate the population density map of the specific age group to be examined.
3. Obtain suitable road network layers or layers of areas that are important hot spots for pollutant emissions.
4. Produce strips at 50m, 200m and 350m distance from each side of these roads.
5. Overlay the maps from steps 2 and 4 and then intersect the data to calculate the population affected in the buffer area.
6. Sum the totals for the whole country or the region of interest.
7. Repeat the process by changing the areas of interest in step 3 (e.g. ports)
8. Repeat the process when new data on the road infrastructure or population data become available (ideally every five/ten years).

In Figure 2 is shown a composite image of population density and the road network with heavy traffic in the greater London area. Roads with high traffic are considered to be: motorways, national roads with double lanes, national roads and other principal roads as classified at the GISCO by Eurostat. For reasons of simplicity, population densities less than 100 inhabitants per km^2 are represented in white.

Current knowledge of health consequences from atmospheric pollution could be then used for calculating the consequences for sensitive population groups. One such group is considered to be the children up to four years old who live either in the vicinity of roads with high traffic flows or near ports or major ferry lines

This information can also be superimposed on maps of atmospheric pollution and noise levels in order to identify hotspots for these particular problems. These variations in the future will help to provide an assessment of where health

statistics diverge from the national mean and indicate if improvements due to reducing air-pollution levels would be feasible. For such comparisons, pollution maps (e.g. PM_{10}, $PM_{2.5}$, ozone and noise) of high spatial resolution are needed. These could be obtained from measurements, modelling or satellite observations with instruments such as the Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY).

Maps obtained from the monitoring networks are not so suitable due to the low spatial resolution provided by monitoring sites and the scarcity of the number of stations in the various Member States, despite the European directives concerning the monitoring and reporting of atmospheric pollution. Furthermore, the data from such stations frequently have temporal availabilities below 85%.

Maps produced by modelling are geographically consistent and can in theory provide information at resolutions of less than 1x1 km^2 but are uncertain due to the inaccuracies emission data. They require spatial and temporal validation. This causes problems even for the combination of the previous two methods utilising assimilation techniques.

The third option, of utilising satellite observation with instruments like SCIAMACHY (ESA, 2005), is realistic and uses comparable and standardised tools. It has three different viewing geometries: nadir, limb, and sun/moon occultation, which yield total column values as well as distribution profiles in the stratosphere and (in some cases) the troposphere for trace gases and aerosols. However, the technique provides total column concentration in resolutions which are coarse for identifying health effects (limb vertical $3x132km^2$, nadir horizontal $32x215km^2$). Furthermore, it is not yet possible to acquire observations of several images per day over the same location.

The composite information of Figure 3 refers to children living within proximity of 50m from main traffic sources in EU member states for 2000. , ISO 3166The percentages refer to the overall number of children in this age group for 2000 (WHO, 2007).

Based on the last figure, countries with higher population appear to have more children exposed due to proximity to roads. 2% of children between zero and four years old appear to be exposed to risks due to the vicinity of main roads at a distance up to 50m from each side of the road. In countries with a dense road network, more children are affected in the specific age group examined. Countries (LU, BE, ES) with high average population densities have a high percentage of children exposed to traffic sources. For distances of up to 350m from each side of roads, a significant number of children of 0-4 years are exposed to atmospheric pollution in particular at metropolitan areas with high population density.

Further improvement of this methodology can be achieved with:
- Spatial updates incorporating different distances from roads, ports, ferries or industrial installations,
- Other vulnerable population groups can be considered according to health effects,
- Better identification of roads with different traffic loads (vehicles per hour),
- Annual variations of population and the attribution of children at the age group of 0-4 years old,
- Seasonal variations within a year of population, traffic density, air pollutant concentrations and statistics of health effects.

1. Examination of provincial mortality and identification of areas that are significantly higher than regional and national data.
2. Evaluate and confirm the temporal variation by examining rates of the mortality for 20-30 years
3. Identify areas at high resolution ($5-10m^2$) with intensive agriculture in the vicinity of urban or semi-urban areas.
4. Examine the type, periodicity and duration of agriculture during the annual cycle.
5. Verify the temporal evolution of land claimed for agriculture against the natural background from satellite images over 20-30 years.
6. Compare the local age-pyramids of populations against the average provincial data.
7. Establish the excess mortality in number of persons and its evolutions in the same temporal period.
8. Overlay maps of high population density and agricultural activity for identifying zones of downwind risk and for recommending protection strategies.
9. Through a series of frequent remote images identify illegal changes of natural background and violations of local and European legislation near urban areas.
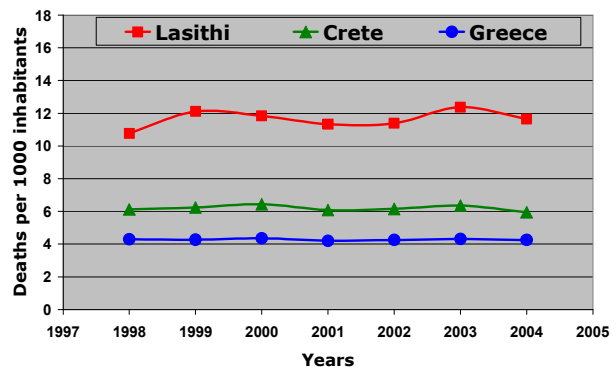

Figure 4. Differences of provincial (Lasithi), regional (Crete) and national mortality on rural and semi-urban population in Greece.

Figure 5. Areas of rapid change in land-use changes due to intensive agricultural production in Greece.

This method has been implemented in several areas of Europe although here are shown examples only from Greece. In these regions the land changes, the population density and the mortality rate have been examined for the same area. Figure 4 shows that the mortality from all causes for the provincial data is three times higher than the national rate and twice the values of the regional data. In Figure 5 is shown an area with a significant increase of greenhouses with intensive agricultural production.
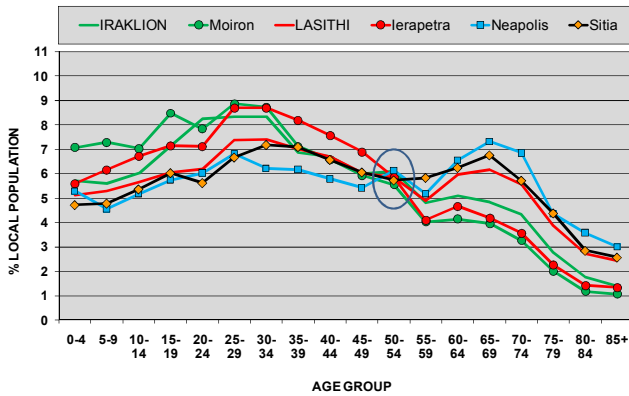
Figure 6. Age-groups in areas with and without intensive agriculture and the comparison with provincial data.

The induced excessive mortality in this area is not only influencing the epidemiological causes of death which are usually difficult to obtain at local scales. We focus on the data above the group of 50-54 years old which are the groups influenced most due to this cumulative hazard. This is also evident in the population distribution per age group. Figure 6 shows the data in two areas of intensive agriculture zones at the municipalities of Moiron and Ierapetra and the corresponding data in zones without such activities in two near by provincial areas.

Figure 7. The evolution of age-pyramids in 1981, 1991 and 2001.

The deviation from mean provincial statistics between 1981 and 1991 is demonstrated in Figure 7 during a period when the area covered by greenhouses had tripled. By integrating the difference of the data from 50+ years old, the 2% difference from the provincial data in 1981, increased to 11% and 10% in 1991 and 2001, respectively. This is equivalent to an excess mortality of 1042 and 1231 persons respectively. These numbers will continue to increase due to migration of labour and population increases especially for the age group of 20-49 years old.

Similar trends have been observed for Spain and Italy in zones with similar characteristics. This methodology can be further extended for incorporating indicators and data:
- Linking the temporal use of water and pesticides.
- Evaluation soil and water contamination.
- Examining the evolution of the climatic conditions for the same period.
- Identification of seasonal variations of the labour force and epidemiologically follow the health status for other origins.
- Linking health data to local fiscal data and the consumption of medicines.

Finally, high resolution satellite multispectral observations taken at regular intervals can identify residuals from the use of pesticides and to calculate the exposure for nearby populations or directly for workers in the fields.

4. PROSPECTIVES AND FINAL REMARKS

Effective legislative policies need to consider the accurate temporal representation of random human activities with satellite observations obtained from several sources.

Human interventions on land and the continuous modification of its use, not only influence the local climate, but are inducing evident health hazards to neighbouring urban or semi-urban populations. This methodology is developed from the systematic observation of areas where natural tree zones are converted in areas of intensive agricultural production. Satellite observations were utilised in order to identify areas where the rate of change for agricultural use has significantly increased over recent years. This approach is for general exposure in areas where the hazards from chemical substances leads to evident health consequences on local populations. This methodology consists of:

Ideally, this will change significantly as the use of new technologies for providing more frequent satellite monitoring becomes available, allowing real-time information regarding the location of vulnerable population groups and the identification of the causes of environmental problems.

In addition, the advancement of technologies for information systems over the last 20-30 years has made available a set of techniques for effectively connecting environmental and health data. This work has introduced two methodologies that examine the challenges for research in areas where data are available and impact assessments are feasible and for the attribution to environmental causes.

Over the short and medium term, it is possible to identify the synergies between exposure and environment and attribute effects on population groups according to age or occupation. Merging relevant layers of information is also feasible for the creation of comparable standardized maps, for exploiting environmental resource data bases in a more timely and cost-effective way, for integration of recommendations in harmonized monitoring systems, for testing through the integrated health statistics, and for analyzing occupational exposure effects such as toxic substances in agricultural areas.

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