

THE ROLE OF A SATELLITE INTELLIGENT SYSTEM IN THE DEVELOPMENT OF A DEDICATED HEALTH AND ENVIRONMENT SPACE-BASED MISSION

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ABSTRACT:

Satellite remote sensing for disease surveillance will play a major role in public health in the coming years. Although the ability to predict epidemic outbreaks is still limited by current research and technology, satellite remote sensing has the potential to become an important tool for assisting epidemiologists in locating areas where disease outbreaks are likely to occur. This will permit the optimization of resources and save lives, especially in developing countries where health related resources are limited and disease outbreaks have far-reaching social and economic consequences.

In order to make satellite sensors reliable tools for epidemiological research, we need to improve upon the capabilities of the current sensors, which are providing data on key epidemiological variables. The most useful remote sensing systems for public health applications will require instruments which can integrate data and information among spectral, spatial and temporal characteristics of remotely-sensed images and disease vector profiles. The ultimate goal of an optimal sensor system, however, is to achieve the capability of using remote sensed data to monitor areas in real time and predict disease outbreaks so that effective preventive actions may be taken. This goal could be accomplished through the creation of a dedicated mission comprised of a collection of instruments and sensors tuned to acquire information directly related to the disease organisms, vectors, reservoirs, hosts, geographic specifications, and environmental variables associated with health problems.

To take advantage of the intelligent space-based remote sensing systems potentially available by 2010 and beyond, we propose to initiate the process of selecting the ideal suite of measurements needed for the development of a dedicated Health and Environment satellite mission. The project will combine the flexibility and expertise in data management and product generation provided by the Center for Earth Observing and Space Research (CEOSR) in the George Mason University (GMU) and its long-standing relation with the NASA Goddard Space Flight Center (GSFC).

1. INTRODUCTION

The use of satellite remote sensing (RS) data in human health studies has been a slow and continuous process taking place over the last 30 years (Albert et. al 2000, Beck et. al 2000, Hay et. al 2000). Many past studies have focused on the use of environmental satellites that provide information on land cover (Landsat, SPOT), vegetation phenology, or surface climatic conditions, such as temperature (AVHRR, GOES). These variables are utilized in studies of vector borne disease, to identify habitats for pathogens and to determine times when outbreaks of pathogens are most likely to occur. Geographic Information Systems (GIS) (Albert et. Al 2000) and modeling are other spatial methods that can be applied to human health studies. RS data can provide input to both of these methods. Ground based or aircraft flown remote sensing instruments are excellent ways of collecting regional data and have the advantage of being able to easily deploy the latest technologies. Many types of RS instruments have applications that are only possible from air flown or surface instruments, even though they may have other types of applications from space. To see the power of a surface remote sensing instrument one only needs to look at the March 2002 issue of National Geographic, which shows the use of NEXRAD in tracking insects and bats. However, space based RS provides measurements with a spatial coverage and temporal frequency that is unique. This discussion will attempt to provide a brief overview of space based RS studies of vector borne diseases, with an emphasis on requirements needed to develop an operational system as well as future development needs. RS has been applied to other areas of human health research, such

as environmental exposure studies and allergy studies, however these applications will not be specifically mentioned in this discussion.

NASA pioneered the use of remote sensing data for human health in the early 70's with the creation of the Health Applications Office (HAO) at the Johnson Space Center (Fuller, 1972). In 1985 NASA began the Global Monitoring and Human Health (GMHH) program for the purpose of determining the applicability of RS and GIS technologies in human health research. The program was based at NASA's Ames Research Center, and performed research on vector borne diseases, such as malaria and Lyme disease. In 1998 NASA created the Center for Health Applications of Aerospace Related Technologies (CHAART), also based out of Ames Research Center. This project focus was on evaluating current and planned satellite sensors systems, to determine if the data could be applied to human health research in the area of landscape epidemiology. Over 17 vector borne diseases including Cholera, Malaria, Lyme and Schistosomiasis (<http://geo.arc.nasa.gov/sge/health/bydisease.html>) have been studied using a variety of satellite instruments. More recently, NASA has developed a new Earth science and public health program, named the HealthyPlanet (<http://healthyplanet.gsfc.nasa.gov/>). The program is based out of NASA's Goddard Space Flight Center and is designed to apply remote sensing data and technologies toward better understanding the links between human health and the environment and weather/climate, and to develop powerful new tools for health-related surveillance and early warning systems.

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There is now a need to move from an application research environment to one that is more of an operational setting and to think specifically about the requirements of human health research, when developing new satellite instruments. Increase global travel and global trade as well as global climate change and other factors have increased the spread of pathogens and intrusive plants on a scale previously not imagined. We can only expect this will continue to increase. The solutions to these problems are inter-disciplinary and as a result require a systems approach. Therefore, the traditional use of RS/GIS in the study of human health needs to evolve.

Besides the improvements in the spatial, temporal and spectral resolution of the future satellite sensors, we also need a better understanding of the relation between the environmental variables and the nature of the disease organisms, their vectors and reservoirs. Only the integration of remote sensing information, environment, epidemiology and entomology on a common framework as GIS can offer the necessary condition for the creation of surveillance programs for operational applications. Such system will require the constant feeding of real-time data and information about environmental changes, habitat modification, human presence, rapid weather variations, etc.

2. DATA ACCESS AND INTEROPERABILITY

One of the most critical points of improvement is accessibility to remote sensing data sets, and the ability to easily use data products from different sources together. There are a relatively large number of sources (<http://geo.arc.nasa.gov/sge/health/sensor/cfsensor.html>) for satellite remote sensing data, but the ability to acquire them and easily use them together varies widely. A number of barriers exist including cost, accessibility, usability, timely-ness, and the sheer volume of data. Unfortunately, most of the remote sensing data acquired in the last 30 years has been geared for scientific applications and as a result accessible only to the scientists that use them. It is also true that a tremendous wealth of information has been generated with very little application and operational concerns

in mind. Here lies one of the most difficult challenges in turn this information to specialists from other areas of expertise as health and environment.

Data from the low-resolution meteorological satellites, such as the NOAA Polar Operational Environmental Satellite (POES) series or NASA's Terra (<http://terra.nasa.gov/>), are generally free. However, accessibility to them can vary, and it can be difficult to get higher-level geophysical variables that are reliable and applicable to human health studies. Data from these types of satellites are best used in time-series studies that can be on the decade scale (Anyamba et. al 2002, Tucker et. al 2002). Time-series studies are very powerful in that they enable comparisons of present conditions with past history showing current anomalies relative to the historical record. These types of studies require data from multiple versions of an instrument, such as the Advanced Very High Resolution Radiometer (AVHRR), which is one of the instruments on the POES. To produce higher level parameters, such as surface temperature, that are comparable over the duration of the instrument series, the data has to be calibrated to take into consideration differences in versions of the instrument, and degradation of the instrument and satellite orbit over the duration of a mission. Additional corrections for view geometry, atmosphere and Bi-directional Reflectance Distribution Function as well as accurate mapping of the data are also required. Higher resolution data from instruments such as the Enhanced Thematic Mapper Plus (ETM+), on Landsat-7, also require similar correction for inter-comparison of scenes.

The NOAA/NASA Pathfinder programs (Maiden and Greco, 1995), were an early attempt to deal with these issues across different satellite platforms. The project came out of part of NOAA and NASA's contribution to the U.S. Global Change Research Programme (USGCRP). A key aspect of Pathfinder was the development of standard data products, using community consensus algorithms that had some level of interoperability between them. These products (table 1) were archived at data centers that distributed the data freely to the user community.

Table 1. NOAA/NASA Pathfinder Programs and Archives

Satellite/Instrument	Data Archive	Data Product
NOAA POES/ AVHRR	GSFC DAAC EROS DAAC JPL DAAC LaRC DAAC	8-km land products (NDVI) 1-km land products (NDVI) 9-km ocean product (SST) Atmospheric products (CLOUDS)
TOVS	GSFC DAAC	1 degree atmospheric profiles
Landsat TM	EROS DAAC	Landsat TM scenes
GOES	VISSR/VAS	Imager and sounder data
DMSP	SSM/I	Hydrology products (precipitation)

The Pathfinder programs had various degrees of success and longevity, but in the end suffered the most from lack of product evolution. Many of the Pathfinder's were not able to continually revise their algorithms taking advantage of the latest science. In the end the Pathfinder's were not able to reach their final goal of providing data products that could be related to products created from new more advanced

instruments, such as MODIS. When Pathfinder began, in the early 1990's, the volumes of data they were dealing with (GOES, AVHRR...) were enormous. However, by the end of the program technology had advanced so the volumes were relatively small compared to more recent data sets such as data from MODIS on NASA's Terra satellite. This presents an interesting possibility of going back and reprocessing the data,

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since the volumes are no longer as formidable. The historical records from these instruments are priceless and making products that are more compatible with data from instruments such as the Moderate resolution Imaging Spectrometer (MODIS), an instrument on board NASA's Terra satellite, would be a great benefit to areas of research such as Human Health research.

NASA's Earth Observation System (EOS) series of satellites (Terra, Aqua, Aura) are multi sensor platforms that are designed to study global climate change. Instruments such as MODIS and Aster have similarities to AVHRR and TM, respectively, but are more advanced in some areas. From the beginning EOS was designed with a long-term data processing and archiving plan. A system was developed, where implementation of new algorithms was incorporated in the design. Many of the higher-level parameters being developed from MODIS, such as Land Cover, Leaf Area Index and Surface Temperature are directly applicable to epidemiology and public health studies. The major draw back is that these are new instruments and obviously do not have the historical record of AVHRR or Landsat.

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) will be the next generation of NOAA's POES and the Department of Defense (DOD), Defense Meteorological Satellite Program (DMSP). These two systems will be merged into one satellite series to reduce duplication of government services and therefore hopefully save money. The program will be on the scale of NASA's EOS project, if not larger, and will provide many of the same applications. However, accessibility to the data, by the public, will be limited in comparison to the POES and EOS series of satellites, as a result of its association the DOD.

In recent years many commercial Earth observing satellite systems have been launched. These include high-resolution satellites such as ICONOS (1 meter) and advanced technology satellites such as RadarSat (SAR). However, these data are not cheap with prices for a single image being in the thousands of dollars. This is usually the determining factor on whether the data can be used in a study, and many times leads to limiting the use of commercial data.

3. POTENTIAL SOLUTIONS

The key to using RS in future human health studies are having accurate, affordable, reliable, and accessible sources of satellite derived geophysical parameters. At the same time there is a need to continue developing and deploying new instrument technology that provide better insight into problems. New instrument technology, including hyper-spectral, SAR interferometers, and motion sensing synthetic aperture radar need to be analyzed for application in human health research. Systems such as EOS and NPOESS that incorporate multi-satellite systems, data production facilities and data archive and distribution abilities, need to continue. There is also a need to continue working with the historical satellite data, such as AVHRR, improving the accuracy of products and merging them with data from the newer satellites. In both cases the distribution of the data needs to be flexible enough to support different data formats and map projections. Cross calibration of instruments and algorithms is critical to these efforts and should be a key area of research for future instrument development. The ability to cross calibrate with

respect to instrument, spatial resolution, and time would allow comparison of data that is now very difficult if not impossible.

While the development of a completely dedicated health and environment space-based mission may not be possible by 2010, much can be done to extract the necessary information from the current and future satellite missions. This include linking basic research, processing capabilities, training and outreach with operational health and environmental applications and establishing stronger connections between the RS data/product generation centers and decision support systems like the Center for Disease Control (CDC) and the Pan American Health Organization (PAHO). Such actions will permit the optimization of the resources currently available for health and environmental applications and allow necessary changes in the planning phase of the coming missions to accommodate the needs of operational applications in these fields. On the other hand, the experience gained in the management, organization and delivery of remote sensing data as well as product generation and integration by institutions like the Center for Earth Observing and Space Research (CEOSR) in the George Mason University (GMU) are crucial. By focusing on research done from satellite platforms, including data, associated information technologies and applications as well as fundamental science, CEOSR works as an interdisciplinary research center. It provides needed infrastructure, including organizational and logistic support to research projects falling naturally within the focus of health and environmental issues.

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