

INTEGRATED SYSTEM FOR HEALTH APPLICATIONS OF EARTH SCIENCE REMOTE SENSING DATA

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ABSTRACT:

There is an increasing demand by the health community for improved data on many different environmental factors pertinent to the links between the environment and disease occurrence and transmission. These data are important for monitoring, risk mapping, and surveillance of epidemiological parameters on a large number of different spatial, temporal, and spectral resolutions. New systems are proposed for improved manipulation and integration of both health and remotely sensed environmental data for better understanding the complex environmental factors influencing the dynamics of vector-borne diseases, such as vectors, reservoirs, hosts, and geographic locations. Studying these complex interactions requires systems that extend the use of remote sensing data beyond the research community to operational disease surveillance and control. In order to create an operational data system for health issues, it is important to first demonstrate that remotely sensed data are being used successfully for health applications. Then, it is necessary to develop and/or learn to use tools that could assist in the detection and mapping of relevant environmental variables and relate them to the distribution of vector-borne and other diseases.

The current system under development at the NASA's Earth Science and Public Health Program is designed to provide quick and easy access to remote sensing data to individuals responsible for making decisions about the control of the occurrence and outbreaks of environment-related infectious diseases. The focus of the program is to create personalized tools to serve the needs of users with very little knowledge in the field of remotely sensed data acquisition and manipulation, but have an important role in the decision-making processes at the local, state and federal levels. Our purpose is to create a system that helps to decrease the gap between the remote sensing science/research community data producers/users and the operational/application users in the medical and epidemiological fields.

1. INTRODUCTION

NASA's unique capabilities to collect and present information in a global context provide an important technological contribution to research and modeling scenarios in environment and health. New measurements and analytical tools are key in improving support to established and emergent themes as well as new initiatives. Better and simpler tools for understanding health and environment links could provide useful information to the health science communities and, in turn, generate benefits such as improved health of the population, decreased mortality rates, diminished loss of productivity due to disease and illness and improved living standards. In order to implement systems to expedite the transfer of environmental information to environment-health research and response communities, it is important to develop user-friendly systems for quick access to Earth science data, recent scientific findings, numerical models, and technological breakthroughs to address health issues and to develop practical and operational Early Warning Systems.

Effective implementation of these systems requires the promotion of both public and private sector use and dissemination of Earth science data/products and effective technology transfer in order to extend the use of NASA's research contribution beyond the traditional science community to be applied to the needs of all levels of government and local users. This, in turn, requires the development of more efficient ways for the diffusion of remote sensing data, value added

products, technology and concepts for application of these technologies to public health.

In particular, remote sensing data combined with geographic information systems (GIS) and global positioning systems (GPS) are fundamental tools for the planning, analysis, surveillance and intervention in the control and management of infectious diseases outbreaks. To take full advantage of these technologies, they need to be fully integrated with one another in order to benefit the end-user in a timely and cost-effective way.

2. LIMITATIONS IN THE USE OF REMOTE SENSING FOR HEALTH APPLICATIONS

Many factors have hindered the use of remote sensing data for health applications. Some of the most important are:

1. Lack of appropriate spatial, temporal and spectral resolution measurements by the current satellite sensors.
2. Lack of good communication and understanding between the remote sensing data producer community and users in the health and environment fields of research.
3. Complexities associated with health and environment relationships due to the diversity and number of variables.

4. Absence of continuous temporal and spatial data sets required for the study of specific diseases or health related problems.
5. Difficult access to data and value added products due to differences in format, resolution, projection, computer systems and lack of an integrated system with generally accepted standards for unified studies.
6. Cost and limited access to high-resolution satellite remote sensing data.
7. Insufficient technology transfer methods to move from research to operational environments.

Many of these problems are being indirectly addressed as a result of a steady increase in the number and sophistication of satellite remote sensing systems recently or soon to be launched. However, a focused effort is needed to improve the technology transfer and the development of user-friendly tools for the mass distribution of data and products.

3. NASA'S EARTH SCIENCE AND PUBLIC HEALTH PROGRAM

NASA Earth Science Enterprise (ESE) and the Goddard Space Flight Center (GSFC) have created the NASA Earth Science and Public Health Program to apply space-based remote sensing data and technologies to better understand the links between human health and the environment, weather and climate, and to develop powerful new tools for health-related surveillance and early warning systems. It is a "collaboratory" effort where scientists from many different fields work together to share data and knowledge to help decision-makers address important health and environment issues.

The following projects are currently under way in NASA's Earth Science and Public Health Program:

1. Ecologically-Coupled Vector-borne Disease Detection Project
2. Childhood Asthma in the City of Baltimore, MD, USA.
3. Mekong Malaria and Filariasis
4. African Dust and Health
5. Cities: Air Pollution and Heat
6. West Nile Virus and Lime disease
7. Environmental Determinants of Vector-Borne Disease

A complete description of these projects may be found at the program web site address:

<http://healthyplanet.gsfc.nasa.gov>

4. DATA/PRODUCT DISTRIBUTION

The NASA/GSFC Earth Science and Public Health Program is currently in the process of developing a user-friendly system to bring land, atmosphere and ocean remote sensing information to users not familiar with satellite data/products in their original format, with an emphasis on GIS-based data. The project consists of the implementation of a multi-scale data/product base of remotely sensed imagery readily available to GIS users from the local to the regional level, mainly targeted for health related applications. This will be accomplished by 1) providing satellite data/products accessible to ArcGIS clients (ArcView, ArcEditor, ArcInfo) and 2), assisting in the establishment of local and specialized GIS databases and ArcGIS servers. See figure 1.

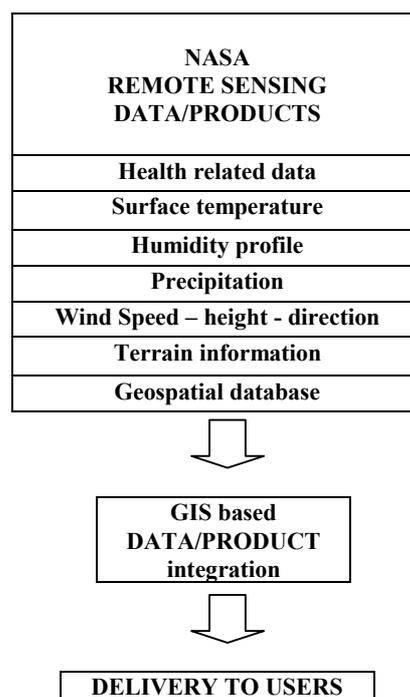


Figure 1. NASA GIS-based data/product delivery system under development.

Until an all GIS-based data system is widely available to the health and environmental communities, we are providing guidance to individual users on the process of accessing and using satellite remote sensing data from both NASA and other organizations. Considering that many users have limited knowledge about the manipulation of raw remote sensing data, our main concern has been the selection of high level remote sensing products that are already available free of cost through the internet. Fortunately, some institutions already make their satellite products readily accessible in image format and provide simple browsing capability for data and product selection. In this initial phase of system development, the emphasis is on directing potential users to these sites and assisting them in the processing of getting the remote sensing product to immediate use for health and environmental applications.

The following section provides examples of some of the products available now accompanied by partial explanations from their associated websites.

4.1 Rainfall Estimation

4.1.1 Real-Time Rainfall Rate

High-resolution real-time rainfall rate estimates over North, Central and South America plus The Caribbean. This product is based on cloud top temperature measurements from the GOES geosynchronous satellite 10.7 micron infrared channel and available on a experimental bases by the National Oceanic and Atmospheric Administration, NOAA. The instantaneous rainfall rates as well as 1-, 3-, 6- and 24-hour accumulations are available every half hour with a resolution of 4 km in both image and digital GrADS file format.

Web site: <http://orbit35i.nesdis.noaa.gov/ard/ht/ff/index.html>.

Provider: NOAA / National Environmental Satellite Data, and Information Service - NESDIS.

4.1.2 Tropical Rainfall Measuring Mission – TRMM

Online analysis TRMM derived monthly and daily rainfall products. Tools for plotting rainfall averages (area plot) and time series (time plot) for selected areas and time periods are available.

TRMM monthly rainfall products web site:
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/trmm_online_analysis/TRMM/TRMM_3B43_ana_v12.html.

TRMM daily rainfall products web site:
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/trmm_online_analysis/TRMM/TRMM_3B42_ana_v1.html.

Provider: National Aeronautics and Space Administration NASA, Goddard Space Flight Center – GSFC, Distributed Active Archive Center - DAAC.

4.1.3 Global Precipitation Estimation – Access to Global Digital Precipitation Product

Monthly mean precipitation data provided by the Global Precipitation Climatology Project (GPCP) on 2.5 x 2.5 degree latitude-longitude grids for the period 1986-2000.

Web site: <http://orbit-net.nesdis.noaa.gov/arad/gpcp/>.

Monthly 1x1 degree merged precipitation estimates from low-orbit satellite microwave data, geosynchronous-orbit satellite infrared data, and rain gauge observations for the period covering Jan 1979 to Jan 2001.

Web site: http://yang.gmu.edu/~yang/nasacd/www/gpcp_global_precip.html.

Provider: NASA / DAAC - National Aeronautics and Space Administration / Distributed Active Archive Center.

4.2 Wind Speed, Direction and Height

4.2.1 Upper Atmosphere Winds

Experimental real-time high-density upper atmosphere wind estimates from GOES satellite data are maintained by the NOAA/NESDIS. The GOES-East/West products show wind speed, direction and heights covering the East/West USA, Central America and the Caribbean region. Using various techniques the following products are available: Water Vapor Winds, Infrared Cloud-Drift Winds and Visible Cloud-Drift Winds.

Web site: <http://orbit35i.nesdis.noaa.gov/goes/winds/>.

4.2.2 Sea Surface Winds-

Global, near real-time high-density 22 hours composite of sea surface winds derived from the QuickSCAT, ERS-2 and DMSP/SSM/I.

Web site: http://wwwo2c.nesdis.noaa.gov/owinds/winds_browse.htm.

Provider: NOAA/NESDIS

4.3 Sea Surface Temperature - SST

GOES derived SST composite products are available in near real-time through the NOAA CoastWatch Ocean Product Server. Hourly images are composed every three hours and then posted in the Web. Imagery is available in a variety of formats and retrospective imagery (older than 2 days) may be ordered through the Satellite Active Archive (SAA) in the near future.

Web site: http://wwwo2c.nesdis.noaa.gov/cwatch/gsst_browse_framed.htm.

Provider: NOAA/NESDIS Satellite Active Archive – SAA.

4.4 Sea Height Anomaly - SHA

SHA and Significant Wave Height data are available in a near-real time basis with a 2-day average delay. These products are derived from the TOPEX/Poseidon satellite orbiting 1336 km above the Earth. The height measurements of the ocean surface directly underneath the satellite have an accuracy of 4-5 centimeters. Interpolating data corresponding to a 10-day period ending at the selected date generates SHA maps. The 10-days period is the time the TOPEX/Poseidon needs to cover all the oceans.

Web site:
<http://www.aoml.noaa.gov/phod/dataphod/work/trinanes/INTERFACE/index.html>.

Provider: NOAA/NESDIS – NASA

4.5 SeaWiFS Chlorophyll “a” Concentration and Ocean True Color

Daily near real-time chlorophyll a concentration maps and ocean true color at 4 Km resolution are available in the SeaWiFS interactive region selection site.

Chlorophyll a concentration web site:
http://seawifs.gsfc.nasa.gov/cgibrs/seawifs_subreg_12.pl.

Ocean true color web site:
http://seawifs.gsfc.nasa.gov/cgibrs/seawifs_subreg.pl?N=3.

Provider: NASA/GSFC/DAAC

4.6 MODIS Near Real-time Land Products

The University of Maryland Moderate Resolution Imaging Spectroradiometer (MODIS) Land Rapid Response system has been developed to provide rapid access to MODIS data globally. The daily MODIS RGB imagery is available as produced for channels 1 to 7 and resolutions from 250m to 1km.

Web site: <http://rapidfire.sci.gsfc.nasa.gov/>

Provider: NASA, University of Maryland, MD, USA.

4.7 Near Real-time TOMS Aerosol Conditions and Daily Total Ozone

The Total Ozone Mapping Spectrometer (TOMS) allows observation of aerosols as the particles cross the land/sea boundary including a wide range of phenomena such as desert dust storms, forest fires and biomass burning. The latest 3-day

composite display of TOMS Aerosol Index is available in near real-time through the web site:

http://toms.gsfc.nasa.gov/aerosols/today_aero.html.

Near real-time TOMS daily total ozone column measured in Dopson Units (DU) for the globe are also quickly available on line. One DU is defined to be 0.01 mm thickness at 0OC and 1 atm (stp). This means that if all the ozone over a certain area is compressed down at stp and form a slab 3mm thick, it will correspond to 300 DU. The images and digital values are available in the web site:

http://toms.gsfc.nasa.gov/teacher/ozone_overhead.html.

Provider: NASA/GSFC

4.8 Vegetation Index

The Vegetation Index images are derived from the SPOT-4 polar orbiting satellite Channel 2 (red) and Channel 3 (near infrared) difference $\frac{(3-2)}{(2+3)}$, giving an indication of chlorophyll activity, the Normalized Difference Vegetation Index (NDVI). Four km resolution NDVI images are available for 10-days and monthly periods from 1998 to 2002. NOAA/AVHRR NDVI is also available covering the period 1982 to present.

Web site: <http://metart.fao.org/~gbr/E-VVGTGL.htm>

Provider: ARTEMIS and AGROMET Data and Information, Food and Agriculture Organization of the United Nations.

4.9 Global Real-time Visible, Infrared and Water Vapor Images from Geostationary Satellites

Global, real-time and interactive geostationary infrared, visible and water vapor images from the weather satellites GOES-8/10, GMS-5 and Meteosat-7 are provided by the NASA Global Hydrology and Climate Center in Huntsville, Alabama, USA. This server allows the selection of a single image or animated loops up to 30 images and zoom capability to enhance the resolution around the region of interest.

Web site: <http://wwwghcc.msfc.nasa.gov/GOES/>

Provider: NASA, Marshall Space Flight Center.

5. CONCLUSION

This paper describes some of the problems associated with the transfer and availability of satellite remote sensing data to the health and environmental user community and introduces the program's new system – presently under development - for providing easily accessible land, atmosphere, water and ocean remote sensing information for health applications.

While a full GIS based system for data and product delivery is not yet available, the first phase of NASA's Earth Science and Public Health Program is assisting users in the identification of and access to of satellite data and products already available throughout many of the NASA and other publicly-available websites.