

# **Data Access and Visualization for SERVIR: An Environmental Monitoring and Decision Support System for Mesoamerica**

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## ABSTRACT

NASA Marshall Space Flight Center, the University of Alabama in Huntsville and the SERVIR partners are developing data products, knowledge extraction methods and decision support tools for application to environmental monitoring, disaster prevention and planning for sustainable growth in Mesoamerica. Mesoamerica - composed of the seven Central American countries and the five southernmost states of Mexico - is severely threatened by extensive deforestation, illegal logging, water pollution, and uncontrolled slash and burn agriculture. Additionally, Mesoamerica's distinct geology and geography result in disproportionate vulnerability to natural disasters such as earthquakes, hurricanes, drought, and volcanic eruptions. The combination of space-based observations from NASA's Earth Observing Satellites with information management and knowledge extraction technologies is yielding a robust system for use by scientists, educators, and policy makers. The availability of these new resources enhances the ability to monitor and forecast ecological changes, respond to natural disasters and better understand both natural and human induced effects. In its first year of development and operation the SERVIR project has already yielded valuable information on Central American fires, floods and the first ever real-time data on harmful algae blooms.

## I. INTRODUCTION AND BACKGROUND

Although it has less than one half of one percent of the earth's landmass, approximately 500,000 square kilometers, Central America contains seven to eight percent of the world's biodiversity [1]. The region is home to more than 20 distinct biologically-diverse ecological life zones [2] ranging from coral reefs, coastal wetlands, and Atlantic lowland wet forests, to pine savannas, Pacific dry forests, and montane cloud forests. Central America's globally

significant biodiversity, combined with its small area and high degree of threatened habitat, has prompted the conservation community to designate the region as a biological "Hot Spot" to be prioritized for conservation planning and management [3]. Fig. 1 shows the Mesoamerican Biological Corridor, a rich ecological system stretching the entire length of Central American. The MBC is threatened by human and natural impacts.

The region's rapid population growth, human migration, and slash-and-burn method of agriculture have had detrimental effects on forests, cutting areas of habitat into increasingly smaller fragments. The 1980-1990 annual rates of deforestation in Central America were among the highest in the world [4] and high rates of deforestation have continued throughout the region in the 1990s [5]. For example, the Maya Biosphere Reserve, which spans approximately two million hectares of northern Guatemala, is part of the largest contiguous tropical moist forest remaining in Central America. This once remote and inaccessible forest has experienced high rates of deforestation in the last decade, corresponding to human migration and expansion of the agricultural frontier [6].

Central America is also a natural laboratory for the study of hazards: an area where the tectonics and weather are intense and the risk and impact of natural disasters are high [7]. Examples of recent disasters include Hurricane Mitch and the 2001 El Salvador earthquakes. Hurricane Mitch hit the region in October 1998 and led to over 11,000 deaths, nearly 10,000 missing and millions homeless. It was one of the deadliest Atlantic tropical cyclones ever to make landfall in the Americas, caused extensive flooding, and triggered more than 700,000

landslides [8]. Hurricane Mitch illustrated the interconnectedness of severe storms, storm surge, flooding, and landslides. Regional decision makers desperately need information to understand the effects of these natural and human induced influences. Information is also needed to assess risk, coordinate response, and determine impact following natural disasters.

The SERVIR project is developing a Regional Visualization and Monitoring System that intensively utilizes NASA Earth Science data products and technology to produce new value added information products for use by Central American decision makers, scientists, educators, government environmental ministries and mapping institutes, scientific and educational institutions, conservation related non-governmental organizations (NGOs), and the



Fig. I. The Mesoamerican Biological Corridor

general public [9]. The acronym SERVIR is derived from the Spanish name of the capability: Sistema Regional de Visualización y Monitoreo. SERVIR is a Spanish verb meaning “to serve” or “to be useful”.

The SERVIR project is a collaborative effort among NASA, USAID, the World Bank, and the CCAD. In addition to the above mentioned primary institutions, there are several funded partners providing vital assistance to SERVIR including the UAH Information Technology and Systems Center (ITSC), Science Systems and Applications Incorporated (SSAI), the University of Arkansas’ Center for Advanced Spatial Technologies, and the Computer Science and Mathematics Division at Oak Ridge National Laboratory. Also, there are several SERVIR collaborators including the University of

Maryland, Conservation International, and Oregon State University.

## II. DATA PRODUCTS

A number of significant NASA data sets and technologies have been identified for use in this project. They include MODIS, TRMM, SRTM, MISR, ASTER, Landsat-7, Archive Landsat TM, Landsat TM, and RADARSAT. Others will be added as the project progresses. Both U.S. and Central American researchers can employ interactive analysis and visualization tools to produce hand-crafted analyses and tailored information. Both value-added and hand-crafted products are widely available for use by decision makers at Central American regional, national, state, and local levels.

Decision support products are value-added environmental assessment and disaster management products. These products are tailored for specific applications. They are based on data from NASA, USGS, NOAA, and other sources, and include GIS information and framework data layers. Most of the source data are available in near-real time, or with short time delay via the Internet. Data from these sources is ingested daily and used to generate corresponding rapid response decision support products. A list of current and planned decision support products and their source data sets are listed in Table I.

As of May 2005 several regional products are being produced. Over the course of this project many more are planned. In addition to the current daily products, we expect to produce event driven products such as flood extent in the near future. Additional data sets of greater complexity and increased value will follow later. Many of these products will become candidates for either routine or on-demand automated production. Some may remain semi-automated and event based, others may be hand crafted. The list of products and their characteristics are summarized in Table II. We are working with the World Bank, CCAD, and other Central American organizations to further discover requirements and prioritize new products.

TABLE I SERVIR DECISION SUPPORT PRODUCTS

SOURCE DATA SET	DECISION SUPPORT DATA PRODUCTS – INTENDED USE
MODIS Rapid Response	Rapid response for wildfire detection. Daily state of the region Land Cover Land Use Change (LCLUC)
MODIS/GOES	Rapid response for volcano thermal activity
LIS, PR, TMI (TRMM)	Rainfall/lightning distribution, Orographic effects when compared with SRTM
SeaWiFS Imagery	Coastal and coral reef monitoring; Coastal suspended sediment, circulation, and Red Tide
MISR	Cloud patterns over forested vs. deforested terrain Identification of haze, eruptive plumes, and smoke Analysis of orographic controls on clouds
ASTER	Mapping of hazards and impacts, Digital Elevation Model creation
Landsat-7	Annual LCLUC surveys Coastal and coral reef monitoring
Archive Landsat	LCLUC reference from 1970s through 1980s
RADARSAT	Flood extent in response mode
CIESIN Population Data	Hazard vulnerability evaluation
SRTM	Precision geocoding of other products, topographic applications

TABLE II DECISION SUPPORT PRODUCTS: EXPECTED PRODUCTION SEQUENCE

Current Decision Support Products	
Fire Extent Product	The daily wildfire product is produced using MODIS Rapid Response vector fire extent overlays burned into a MODIS 250m true color image. MODIS RR fire products are used as inputs to create the daily fire extent product.
Harmful Algae Blooms (Red Tides)	The harmful algae blooms product is derived from MODIS data from both Terra and Aqua platforms. The data is processed daily yielding 500m resolution images over the entire region.
Atmospheric Moisture	Visible and IR imagery from GOES is subset over Central America. Multiple Images at 15 min intervals can be combined yielding animations. Data is near real time.
Central America Today Product	This product is derived from the MODIS instruments aboard Terra and Aqua. It is 500m resolution visible imagery subset over the region of Central America. Images are produced daily and are approximately 24 hours old.
Products to be Developed	
Flood Extent Product	The flood extent product will be produced using DFO flood extent polygons burned into a color-coded shaded relief image of the SRTM data. The drainage network and other hydrographic information will also be burned in.
Active Volcanoes Product	This product will be produced using the HOTSPOT thermal flagged pixels burned into the MODIS 250m true color image with volcano names annotated.
MODIS Monthly Change Product	This will be a monthly change product, based on

	the MODIS reflectance daily product. They will be created by differencing MODIS products 30 days apart.
Landsat-7 Annual Change Product	This will be an annual change product, created by differencing the best 2 Landsat-7 images that are approximately 1 year apart.
Urban Change	This product will be created by differencing historical and current Landsat scenes and other best-available historical datasets.
Planned Response Mode Local Products	
Local Flood Extent Product	This will be based on Radarsat (or ENVISAT SAR) inputs from CSTARS. The drainage network and other hydrographic information will also be burned in.
Planned Post Disaster Products	
Landslide Extent	Depending on the magnitude of the event (storm or earthquake) they will be based on Landsat-7, ASTER, or SAR data with manual interpretation
Burn Scar Extent	Depending on the size of the burn scar(s), this product could be produced from either Landsat-7 or MODIS 250m.
Exploratory Product – Considered due to recent Sumatran tsunami event	
Pacific Rim Tsunami Arrival Forecast	The Pacific Marine Environmental Laboratory and the Pacific Disaster Center have operational products and active model development projects in this hazard area.

### III. OPERATIONAL ENVIRONMENTAL MONITORING DATA PRODUCTS

At this publication date there are four environmental monitoring data products available from the SERVIR website. (<http://servir.nsstc.nasa.gov>) Many more are

nearing completion. This section describes those products.

#### A. GOES Weather Images

Data from the GOES satellite is ingested every 15 minutes from an antenna located on the roof of our building in Huntsville, Alabama. This data of the Western Hemisphere is then subsetted over Central America and three sub-regions of Central America: The countries of Guatemala, Belize, Honduras; Nicaragua, Honduras; and Costa Rica and Panama. There are three atmospheric moisture products: visible, infrared, and water vapor. In addition to the latest static image for each data product and region, there are also animations of each product constructed from the previous six images. Fig. II shows a GOES IR Image over Central America.

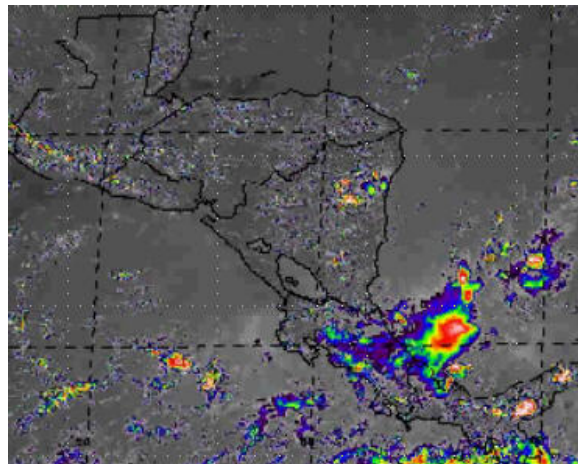


Fig. II. GOES IR image of Central America

#### B. Central American Fires

The SERVIR Fire Rapid Response System generates fire products daily from MODIS data and posts the products to the SERVIR web site. Each day, the Terra spacecraft, with the MODIS instrument aboard, crosses over the Central American region at approximately 10:30 AM local time. Later in the afternoon, the Aqua spacecraft, with an identical MODIS instrument, crosses over the region at approximately 1:30 PM local time. The data are processed in the Rapid Response System into fire products within 3-4 hours after acquisition. The fire products are subsetted over the seven Central American countries and southern Mexico. Images are produced in 1Km, 500m, and 250m resolution. Fig. III shows fires in Guatemala in April 2004. Smoke can be seen trailing from the southwest toward northeast.



Fig. III. An example of the SERVIR fire product with fires (red dots) overlaid onto MODIS imagery.

The SERVIR Fire Rapid Response System is an extension of the MODIS Rapid Response System developed to provide rapid access to MODIS data globally, with initial emphasis on 250m color composite imagery and active fire data. The MODIS Rapid Response Project was developed through collaboration between NASA, the National Oceanic and Atmospheric Administration (NOAA), the University of Maryland, and the USDA Forest Service.

The SERVIR website also links to the University of Maryland's Web Fire Mapper site which provides MODIS fire hotspot data in an Internet Map Server environment.

#### C. MODIS Image of the day

Each day visible images of Central America (Fig. IV) are derived from the MODIS instruments aboard the Aqua and Terra satellites. These images are posted to the SERVIR web site and made available for use. The images generally are one day old. They mainly show cloud patterns and major atmospheric storms developing off the



Fig. IV. An example of a 500 meter MODIS visible image of Central America

coast. MODIS 500 m resolution data is automatically fetched from the Goddard Space Flight Center data pool to create this product.

#### D. Red Tides

Red tide or harmful algal bloom (because blooms can also be other colors) events can make people sick, result in massive fish kills, death of marine mammals and seabirds, and alteration of marine habitats. As a consequence, these events adversely affect commercial and recreational fishing, tourism, and create a significant impact on local economies and the livelihood of coastal residents. The SERVIR project responded to a request from the Government of El Salvador for images of algal blooms (Fig. V) off their coast so that actions could be taken to mitigate the impact upon the fishing industry. As a result there was a savings of many millions of dollars to the El Salvador fishing industry and a reduction in health risk since contaminated fish were not harvested.

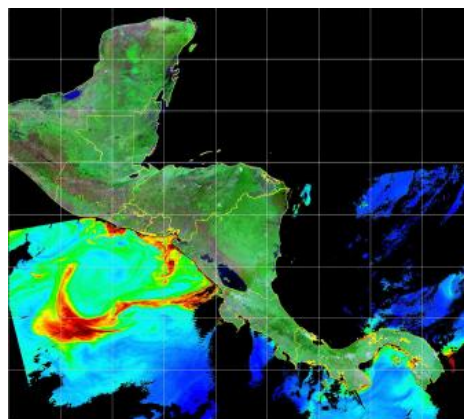


Fig. V. Red tides off Central America.

The most recent MODIS Aqua Ocean Color products are retrieved from the ftp server of the Ocean Data Processing System (ODPS) located at the Goddard Space Flight Center. These products are then further processed to yield the chlorophyll concentration profile over the Central American region. The profile is then color-mapped to create a Red Tide image. Finally, coastlines and latitude/longitude grids are added.



#### IV. SERVIR WEB SITE

The SERVIR project maintains an active and informative web site (Fig. VI) that serves as the primary user access point for information, products and services. All data and products generated by the project are publicly available for direct download off the Internet and will soon be available to the user through online web mapping and web coverage services. Timely access to new data products that accurately depict environmental conditions in detail gives decision makers vital information to rapidly respond to crises situations as well as monitor intermediate and long-term changes. This information is critical in managing the sustained development of Mesoamerica.

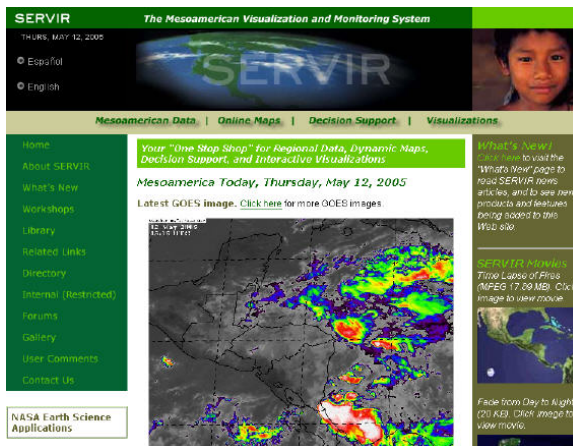


Fig. VI. SERVIR website home page

There are four principal sections to the SERVIR web site.

1) *Mesoamerican Data*: This section provides access to on-line data resources including the central system for SERVIR data located in Panama. This system – known as MesoStor – is an on-line repository of vector and raster data and satellite imagery. Users may access and download data from there.

2) *Dynamic Maps*: Users may access on-line GIS data of Mesoamerica and the individual countries through a Web Map Server interface.

3) *Decision Support*: Here there are links to the most recent decision support products such as fires, red tides, floods and other critical information. Links are provided to valuable products generated by agencies and organizations external to the SERVIR project as well as those hosted by SERVIR.

4) *Visualizations*: The 15 meter mosaic of Central America [10] created by the SERVIR project can be viewed on-line in this section. Data streaming is provided by the University of Alaska Fairbanks. Users can interactively fly over any region they chose panning and zooming as they go. The viewer can be downloaded free from Skyline Software Corporation.

A separate area of the web site is set aside for communications and collaborative efforts among all partners and participating agencies. This internal section gives users the ability to contribute information to the project by entering information and/or uploading files. The web site also offers quick links to four discussion forums. These four forums have been established by the SERVIR administrators. They are:

- Regional and National Node Development
- Land Cover and Land Use Change
- Climate Change and Modeling
- General Issues

These forums are open to the public. No password is required, but users must register in order to post messages.

#### V. SUMMARY

Since October 2003, the SERVIR project has had many accomplishments including development of the web site, creation of initial decision support products (e.g. fires and red tides), two regional workshops (land cover and land use change and climate modeling), and interaction with Mesoamerican scientists and researchers. The first 15 meter resolution mosaic of the entire Mesoamerican region was completed and is available on-line. On February 3, 2005 the project was officially dedicated in a ceremony at the SERVIR node at the City of Knowledge, Panama. Representatives from NASA, The World Bank, the U.S. Agency for International Development, the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC), the Central American Commission for Environment and Development and Cable & Wireless Panama and representatives from all the Central American Countries participated. This event was reported in more than 28 print stories and 60 web news stories including stories in the Los Angeles Times, New York Newsday, the Washington Post and Central American newspapers.

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