SERVIR at the Age of Four: The Development of an Environmental Monitoring and Visualization System for Mesoamerica

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Abstract – SERVIR is a regional, environmental monitoring and decision support system, reaching from southern Mexico to Panama, that monitors and helps decision makers mitigate the natural and anthropogenic impacts on the region through the collection and dissemination of scientifically sound information. The system supports a variety of practical applications, along with enabling research. Building on the capabilities of its partners, SERVIR incorporates data from a network of sensors and linked computers. The system utilizes a rapid prototyping approach that develops, and quickly transitions to operations, new data products and applications from the research community. The SERVIR project currently provides reliable data and information to decision makers, scientists, educators, environmental ministries, mapping institutes, scientific and educational institutions and the general public.

I. Introduction

SERVIR, one of NASA's Research, Education and Applications Solution Network (REASoN) projects, has succeeded in bringing together remote sensed data from NASA's Earth Science missions and regional information held by the countries of Central America with advanced information technology applications to realize a regional, environmental monitoring and visualization system that is giving decision makers in Mesoamerica powerful capabilities to manage their environmental resources and to respond to natural disasters. (The acronym SERVIR is derived from the Spanish name for the project: Sistema Regional de Visualizacion y Monitoreo. SERVIR is also a Spanish verb meaning "to serve" or "to be useful.") Since the dedication of the SERVIR operational node in Panama City, Panama in February of 2004, the SERVIR project has developed into a sophisticated system that is providing information on a daily basis. Since its inception SERVIR has responded to several natural disasters by rapidly providing data products for use by rapid responders. These include Hurricane Stan in 2004 and a massive flood event in November 2006 in Panama. Other information products are widely used in many day-to-day activities including commercial fishing in El Salvador and tourism in Panama. From the initial group of partners funded by the REASoN program, USAID and the World Bank, SERVIR has added many additional partners – most not directly funded - who have created valuable information products for the region. This network of partners continues to grow and there are currently several efforts under discussion to extend the capabilities of SERVIR to other regions on the globe.

The Information Technology and Systems Center (ITSC) at the University of Alabama in Huntsville has been a SERVIR partner since its inception. Teamed with NASA Marshall Space Flight Center and Science Systems and Applications Inc., ITSC has developed much of SERVIR's infrastructure, data management, display and visualization capabilities, as well as the Rapid Prototyping Center (RPC) for SERVIR in Huntsville, Alabama. This paper provides an overview of the SERVIR project and updates the information presented at the 2005 Earth Science Technology Conference [1].

II. Decision support products

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 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 are ingested by the SERVIR archive system as they become available (hourly in some cases) and used to generate corresponding rapid response decision support products. The decision support products are organized along the nine Global Earth Observation System of Systems (GEOSS) areas of societal benefit [2]. A brief summary of each follows.

A. Disasters

Natural disasters, such as hurricanes, extreme weather events, earthquakes, volcanic eruptions, landslides, fires, and floods, are unfortunately common in Mesoamerica [3]. In collaboration with its partners, the SERVIR team produces a variety of real time and near real-time products that relate to fires, hurricanes, volcanoes, earthquakes, flooding, and landslides.

One of the biggest problems in the region is fires [4]. SERVIR produces several satellite-based fire products that are used to monitor the location and extent of fires. The Mesoamerican Web Fire Mapper, Fig. I. developed by the University of Maryland, NASA, and the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC), is an online, interactive map application that displays active fires detected by the MODIS Rapid Response System. In addition, the SERVIR Fire Rapid Response System produces data products for six regions of Mesoamerica, Table I. The products are comprised of MODIS imagery at three resolutions (1.0 Km, 0.5 Km, and 0.25 Km) with fire boundaries superimposed on the images.

TABLE I
MODIS RAPID RESPONSE FIRE PRODUCTS

Product	Start Date	End Date
MODIS 1KM, 500M & 250M Guatemala & El Salvador	February 10, 2004 *	Current Date
MODIS 1KM, 500M & 250M South Mexico & Belize	February 10, 2004 *	Current Date
MODIS 1KM, 500M & 250M Honduras	February 10, 2004 *	Current Date
MODIS 1KM, 500M & 250M Nicaragua	February 10, 2004 *	Current Date
MODIS 1KM, 500M & 250M Costa Rica	February 10, 2004 *	Current Date
MODIS 1KM, 500M & 250M Panama	February 10, 2004 *	Current Date
MODIS 1Km Aqua & Terra	January 1, 2006	Current Date
MODIS 250m Aqua & Terra	January 1, 2006	Current Date
* Data gaps: Oct. 12, 2004 - Jan. 31, 2005 and Dec. 28, 29 and 31, 2005		

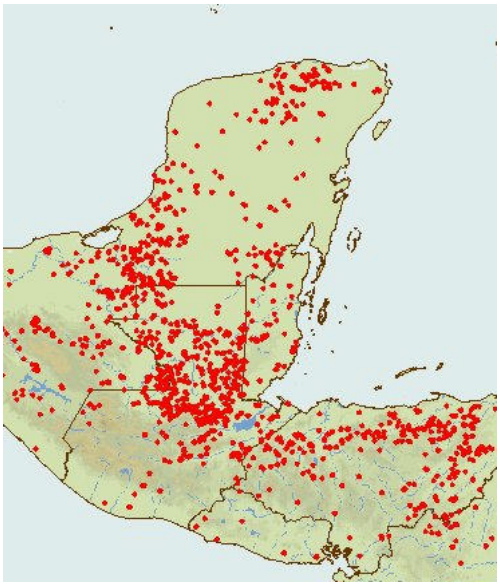

Fig. 1. Fires in Guatemala, El Salvador and Honduras, May 2007 as shown by the University of Maryland Web Fire Mapper

The combination of heavy rain, steep slopes, and in some cases, deforestation, makes landslides a serious risk in Mesoamerica. The USGS mapped 11,500 landslides in Guatemala occurring as a result of Hurricane Mitch in 1998. In response to the need to better plan for landslide events, SERVIR research partner Science Systems and Applications Inc. has generated a prototype regional landslide susceptibility map. Landslide susceptibility is identified using slope and elevation thresholds known to correspond with landslide events.

B. Weather

SERVIR produces short-term regional weather forecasts using the Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model, known as MM5 in the atmospheric sciences community. The MM5 model generates 48 hour-forecasts once a day. Soil temperature, two meter surface temperature, three hour accumulated precipitation as an early warning, wind in different heights, and other variables are forecast hourly in 9 Km grids covering the Yucatan Peninsula to northwest Panama. Additional short-term weather forecasts are produced by the NASA Short-term Prediction Research and Transition (SpoRT) Center. They use the Weather Research and Forecast Model (WRF) to produce 24 hour-forecasts of as shown in Table II. The SATellite Convection AnalySis and Tracking (SATCAST) system produces data products that estimate the flooding potential of thunderstorms as well as land-surface energy and water fluxes on regional scales. These “now cast” products are extremely useful in short term events where flooding and landslide dangers exist. Finally, GOES-12 data is provided for Mesoamerica every 30 minutes under normal operations.

TABLE II
WRF SHORT TERM FORECAST PRODUCTS

3-Hour Precipitation - 10 km & 30 km
Dew Point Temp & Wind - 10 km & 30 km
Humidity & Wind - 10 km & 30 km
Temperature - 10 km & 30 km
Temperature & Wind - 10 km & 30 km
Vorticity & Wind - 10 km & 30 km
Wind & Pressure - 10 km & 30 km

C. Biodiversity

Knowledge of land classification, land cover and changes to these are an important factor in understanding biological diversity. SERVIR provides a substantial cache of data products in this category. Landsat and MODIS-derived land cover estimates and their integration with ancillary climate and soils maps are available. In addition high resolution imagery from Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and elevation data from Shuttle Radar Terrestrial Mission (SRTM) imported into available 2D and 3D viewing applications provide a multi-functional capability to study biological habitats. Representatives from each country in Central America can add their respective GIS data to conduct localized environmental monitoring.

In addition to land cover information the NASA Ames Ecological Forecasting group, in support of SERVIR, is providing a suite of ecosystem nowcasts and forecasts known as TOPS-30. The Terrestrial Observation and Prediction System (TOPS) is a modeling software system that brings together technologies in information science, weather/climate forecasting, ecosystem modeling, and satellite remote sensing to enhance management decisions related to floods, droughts, forest fires, human health, crop, range, and forest production. TOPS Mesoamerican products include 8 and 16-day forecasts for six different variables.

Fig. 2. Leaf area index June 2007 from TOPS

D. Climate

Several new Earth observing satellites, suborbital systems, surface networks, reference sites, and process studies are now producing unprecedented high quality data that have led to major new insights about the Earth-climate system. The SERVIR project, under USAID funding, has developed comprehensive regional climate change scenarios of Mesoamerica for future years: 2010, 2015, 2025, 2050, and 2099. These scenarios were created using the MM5 model and processed on the Oak Ridge National Laboratory Cheetah supercomputer. The satellite derived cloud climatology product quantifies how often clouds are observed over a particular location at a specified time of observation. Frequency of occurrence of clouds (FOC), defined as the percentage of observations for which clouds are observed to be present over a particular location, is computed for monthly and decadal (10-day) periods. For a monthly time period FOC of 50% means clouds were observed over a particular location 15 out of 30 days, while for a decadal time period it means clouds were observed for 5 out of 10 days. Since cloud cover impacts the amount of solar radiation reaching the surface, cloud climatology has several environmental management applications. Cloud climatology is useful for land management planners, for example, wanting to identify farming areas that require shade such as shade coffee.

E. Oceans

Harmful algal blooms (HAB) can make shellfish and other economically important marine life toxic. The SERVIR team employs MODIS ocean color data to generate daily products that enhance current HAB detection systems. The imagery helps determine with a high degree of accuracy the location, direction, and extent of algal blooms. The data products depict chlorophyll in marine environments and serve as likely indicators of HABs.

An unexpected consequence of these products was their acceptance and use by the fishing and tourism industries. The El Salvadoran and Guatemalan governments utilize these products to alert their tourism and fishing industries of potential HAB events. This has enabled these countries to save millions of dollars for their industries.

Another highly used SERVIR ocean data product is Sea Surface Temperatures (SST). The satellite derived SST product is an estimate of the radiating temperature of the top-most layer of the ocean surface, typically less then one millimeter and can often be used as a surrogate for a measure for the heat stored in a greater thickness of the ocean surface layer. SST products help regional environmental and disaster managers by providing a near real-time, accurate, high resolution estimate of the spatial distribution of SST over time. This knowledge, along with other ocean products such as chlorophyll concentration, chlorophyll fluorescence, and even suspended sediment

products, when used in a diagnostic mode or in tropic models can be a significant aid to commercial fishing industries and for ecological forecasting and coastal disaster problems.

F. Water

Heavy rainfalls, a high density of surface water bodies and, in some cases, poor infrastructure make flooding a serious perennial hazard in Central America. SERVIR collaborators provide several products for both monitoring existing floods and analyzing historical events. The Dartmouth Flood Observatory (DFO) utilizing remote sensed data from the AMSR-E instrument is able to determine river discharge and watershed runoff from 25 rivers in Central America. SERVIR publishes this data through a web-map service that automatically updates as new flood data is received (about once every two days).

G. Agriculture and Health

SERVIR data products that relate to agriculture and health also apply to other GEOSS areas. Land cover and land use are obvious examples. In addition, weather and climate products also impact agricultural decisions and lead to conditions that have health consequences. In addition to the land cover, climate, and weather products discussed above, SERVIR teams with the Mesoamerican Food Security Early Warning System Network (MFEWS) to obtain food security information. MFEWS strengthens the ability of foreign countries and regional organizations to manage risk of food insecurity through the provision of timely and analytical early warning and vulnerability information. MFEWS information products are made available through the SERVIR website and visualization tools

H. Energy

SERVIR incorporates the GEOSS societal benefit area of energy by teaming with the Solar and Wind Energy Resource Assessment (SWERA) project. SWERA -- a United Nations Environment Program provides solar and wind energy assessments to potential investors and the public to promote more effective use of alternative energy resources. Four of the thirteen partner countries are located in Mesoamerica.

III. Data Access and Visualization

The production of data and information products has been a major achievement of the SERVIR project. In many instances the suite of data products, numbering over 100, has given environmental ministers and policy makers unprecedented views of their regional geophysical environment. However, the data are only half of the story. The ability to access, manage, manipulate, and display the date is equally important. Toward this end, the SERVIR project and its partners have developed a suite of applications built on a common information architecture, that present the data in easy to understand ways [5]. Several of these applications are discussed below.

A. Real Time Image Viewer

The Real Time Image Viewer (RTIV) is a customized application that can display single images or create an animation from a sequence of images. The viewer, Fig. 3, has a search interface that can be used to query the SERVIR database to locate imagery in either gif or jpg formats. Users may search by GEOSS societal area, keyword, or theme. A time span may also be specified. All images that match the search are returned as a list to the user. Users are then able to select an individual image, or a series of images, to create an animation. The imagery is fetched from the remote servers and then displayed within the browser window. Controls give the user the ability to stop, start, reverse, and single step through the frames. The animations can even be exported as movies for later use.

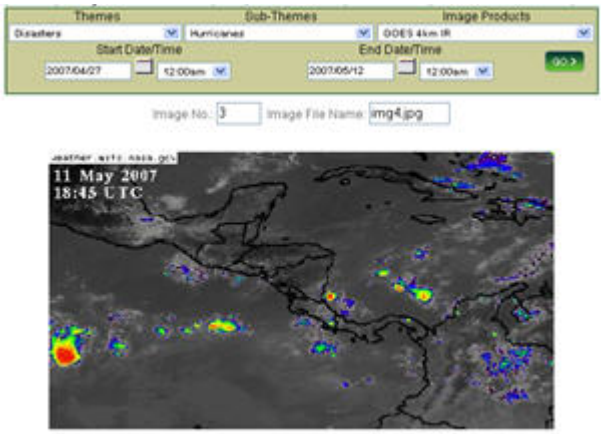

Fig. 3. Real Time Image Viewer showing GOES IR data over Central America

The RTIV also generates KML files for each image in the list. If the user has Google Earth installed on their workstation, the image can be displayed simply by clicking the Google Earth icon from the RTIV. The RTIV can be launched from the following location: http://servir.nsstc.nasa.gov/visualizations/image_viewer.html

B. Map Maker

Much of the SERVIR data is geospatial data. As such it may be viewed with a variety of GIS viewing applications. The SERVIR Interactive Mapper is one such tool. Initially developed by IABIN the Mapper was extended by the University of Alabama in Huntsville to view and query decentralized spatial data from participating institutions throughout Mesoamerica and the Caribbean. Based on the open source Minnesota Map Server and the Chameleon interface toolkit, the Mapper presents a completely open source solution for manipulation of GIS data.

Users can display GIS layers and imagery. Custom products can be produced by combining several layers from different sources. The actual data files are served by a list of web map servers located throughout Mesoamerica and the United States.

The Mapper runs in a web browser and does not require downloads or any special software. The Mapper may be activated from: http://servir.nsstc.nasa.gov/wms/index.html

C. SERVIR-VIZ

SERVIR-VIZ is a customized version of NASA's free, open-source, web-enabled, 3D earth exploration tool known as World Wind. SERVIR-VIZ was developed in a joint effort led by The Institute for the Application of Geospatial Technology (IAGT) – a SERVIR research partner. SERVIR-VIZ provides a virtual globe with custom tools and access to remotely-hosted data layers, maps, real-time satellite images, and other SERVIR products relevant to the Mesoamerica region. SERVIR-VIZ is fully interoperable with NASA World Wind and can be used in conjunction with the numerous plug-ins and add-ons available from World Wind Central. Like World Wind, SERVIR-VIZ is a desktop application. Users must download and install SERVIR-VIZ. The installation package and instructions can be found at: http://servir.nsstc.nasa.gov/visualizations/servir_viz.html

D. SERVIR Data Portal

The SERVIR Data Portal is an online data product and image search system. It was constructed with the powerful ESRI portal toolkit which incorporates numerous features for metadata entry and updates. Following the Federal Geographic Data Committee (FGDC) metadata standards the portal is a comprehensive catalog of all SERVIR information resources. Users are able to conduct searches via a simple keyword search, or more accurate searches may be invoked by selecting the advanced search and entering a more detailed description of the desired geographical region and phenomena of interest. In many cases the portal provides a link to the actual data files for direct downloading. The portal has a built in web map viewer that can be used to construct layered maps of many GIS formatted data sets. The portal may be accessed on line at http://maps.cathalac.org/Portal/

IV. SUMMARY

Perhaps the most significant achievement of the SERVIR project has been to stimulate numerous organizations to extend their research activities and regional monitoring capabilities to address environmental issues in Mesoamerica. As a result a large suite of data products are now being produced at varying geographic resolution and across a wide time scale. The response has been much greater than expected, and the impact to the region has been repeatedly demonstrated.

SERVIR addresses the nine GEOSS societal benefit areas: disasters, ecosystems, biodiversity, weather, water, climate, oceans, health, agriculture, and energy. SERVIR headquarters are located at the Water Center for the Humid Tropics of Latin America and the Caribbean (CATHALAC) in the Republic of Panama. A test bed and rapid prototyping SERVIR facility is managed by the NASA Marshall Space Flight Center at the National Space Science and Technology Center in Huntsville, Alabama.

SERVIR implementing agencies include NASA, CATHALAC, United States Agency for International Development (USAID), the Central American Commission for Environment and Development (CCAD), the World Bank, the Nature Conservancy, and the United Nations Environmental Program (UNEP-ROLAC), the University of Alabama in Huntsville, and IAGT. Private sector Partners include Cable and Wireless Panama and EGE Fortuna S.A.

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