The Namibia Early Flood Warning System, A CEOS Pilot Project

Daniel Mandl[1], Stuart Frye[2], Robert Sohlberg[3], Pat Cappelaere[4], Matthew Handy[5], Robert Grossman[6]

[1] NASA\GSFC Code 581 Greenbelt, Md 20771 USA daniel.j.mandl@nasa.gov
[2] SGT Inc. NASA/GSFC Greenbelt, Md 20770 USA
[3] Vightel Inc. Ellicott City, Md 21042 USA
[4] Univ. of Maryland, Department of Geography, College Park, Md 20740
[5] Code 583 NASA/GSFC Greenbelt, Md 20771 USA
[6] Univ. of Chicago, Chicago, Ill USA
*Corresponding author, email: daniel.j.mandl@nasa.gov

Abstract*— This paper describes a pilot project effort under the auspices of the Namibian Ministry of Agriculture Water and Forestry (MAWF)/Department of Water Affairs, the Committee on Earth Observing Satellites (CEOS) /Working Group on Information Systems and Services (WGISS) and originally moderated by the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER). The effort began by identifying and prototyping technologies which enabled the rapid gathering and dissemination of both space-based and ground sensor data and data products for the purpose of flood disaster management. This was followed by an international collaboration to build small portions of the identified system which was prototyped during the past few years during the flood seasons which occurred in the February through May timeframe of 2010 and 2011 with further prototyping to ongoing in 2012. The pilot effort has been fostered by CEOS to facilitate international efforts to promote satellite sensor data interoperability. In particular, the group has been making use of a technology effort call SensorWeb being developed at NASA which leverages Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) standards to facilitate various satellite and ground sensor interoperability. The group has made use of such satellites such as Earth Observing 1, Terra/Aqua MODIS and the Canadian Space Agency (CSA) Radarsat together with various ground sensors such as river gauges in Namibia and models such as Global Disaster Alert and Coordination System (GDACS) from Joint Research Center (JRC) from the European Commission. Finally, the group has been experimenting with integrating a large Cloud Computing service provided by the Open Cloud Consortium (OCC) with the SensorWeb to provide management and distribution of the large data sets for emergency workers.

Keywords—GEOSS, GEO, CEOS, Disaster Management, Earth Observations, OGC, Interoperability, Architecture

I. INTRODUCTION

Since 2009, Namibia has experienced a surge of flooding in the Northern portion of the country. It was estimated that during 2009, 700,000 of the approximately 2 million people in Namibia were impacted by the floods of 2009, furthermore around 50,000 people were displaced and 102 people lost their lives. Estimated damage and losses during that year in Namibia were at about $210 million U.S., which represented things such as damages to infrastructure and lost capacity in agriculture, industry, commerce and tourism [1]. Similar impacts occurred in 2010 and 2011 from additional large floods during the flood season that had begun occurring during the months of February through May annually. As a follow-up to the assistance provided by the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), National Aeronautics and Space Agency (NASA), Deutsches Zentrum fur Luft- und Raumfahrt *(*DLR) German Aerospace Center, Ukraine Space Research Institute (USRI), and other space agencies in 2009, the "Namibia Flood SensorWeb" project was set up with the purpose of integrating remote sensing into a flood monitoring, and early warning decision support system. The main in country partner was the Namibian Hydrological Services. The vision was to create a decision support system oriented to local user needs, but based on a regional, trans-boundary approach, with Namibia serving as a node country. The decision support system would ingest key satellite and ground sensor data and integrate the information to provide flood situational awareness and early warning. The intent was to facilitate capacity development and institutional strengthening in Namibia to ensure the sustainable use of such a system. A collaborative proposal was developed that outlined the major components needed to build a Flood SensorWeb and a cost proposal was developed. Due to the large cost, the entire effort has thus far not been funded; however, various portions of the team have been working with the Namibian Hydrological Services to deploy portions by leveraging existing funded research along with existing resources at the Namibian Hydrological Services.

II. SENSORWEB

The initial collaboration was initiated by United Nations Office of Outer Space Affairs and CEOS Working Group for Information Systems and Services (WGISS). The initial driver was to demonstrate international interoperability using various space agency sensors and models along with regional in-situ ground sensors. In 2010, the team created a preliminary semi-manual system to demonstrate moving and combining key data streams and delivering the data to the Namibia Department of Hydrology during their flood season which typically is between January through April. In this pilot, a variety of moderate resolution and high resolution satellite flood imagery was rapidly delivered and used in conjunction with flood predictive models in Namibia. This was collected in conjunction with ground measurements and was used to examine how to create a customized flood early warning system. Figure 1 shows a functional view of the Flood SensorWeb architecture.

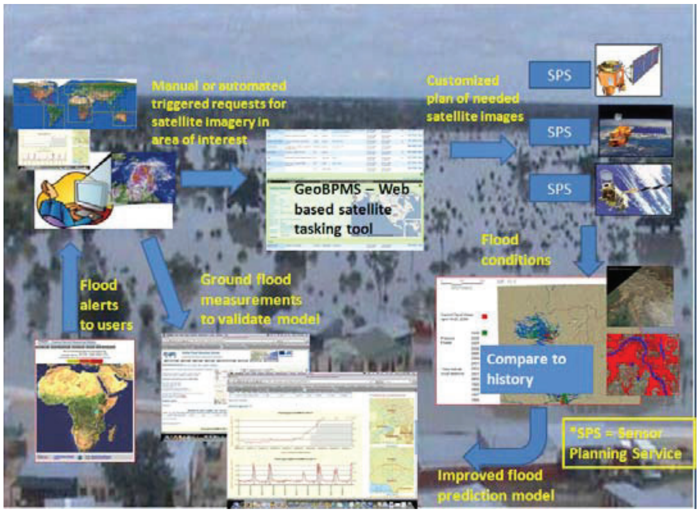

Fig. 1: Flood SensorWeb functional diagram

During the first year, the team made use of SensorWeb technology to gather various sensor data which was used to monitor flood waves traveling down basins originating in Angola, but eventually flooding villages in Namibia. The team made use of standardized interfaces such as those articulated under the Open Cloud Consortium (OGC) Sensor Web Enablement (SWE) set of web services [1][2].

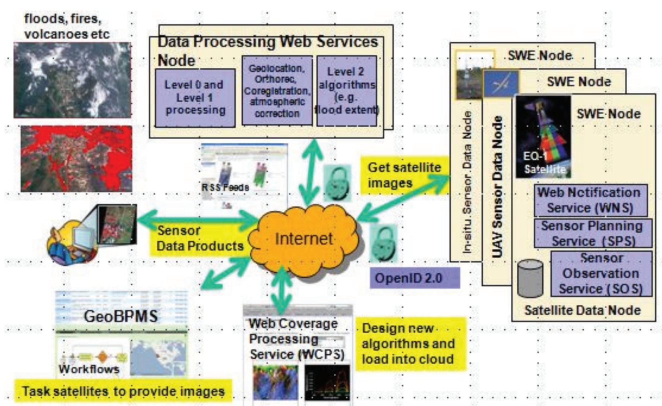

Fig. 2: SensorWeb high level architecture

Figure 2 shows the general SensorWeb components with sensors and data processing components wrapped in standard web services based on OGC SWE standards with extensions. The functionality provided by the basic SensorWeb architecture is the ability to task remote sensors, define processing and delivery methods and provide security for use over open networks. This architecture has been customized for use as a Flood SensorWeb.

Note that there are a variety of types of components that comprise the SensorWeb. The Campaign Manager or GeoBPMS is one of the center piece components and provides a visual interface to allow a user to visually specify an area of interest on a map and then trigger Earth Observing 1 (EO-1) and in the future Radarsat to take an image and automatically deliver it back to the user. There are various Web Notification Services (WNS). But we use OGC Publish/Subscribe Service (OPS) component which allows users to subscribe to various satellite data sets such as those from EO-1. Notification and links to the data are received by the user for the area of interest. Another key component is the Web Coverage Processing Service (WCPS) which enables users to develop new algorithms to run against various data sets. For now, this works with EO-1 data, but will be extended to other satellite data in the future. There are multiple Sensor Observation Services (SOS) to distribute data sets. There are also various Web Processing Services (WPS) which transform raw sensor data to higher level data products. Also there is a component call OpenID Provider (OP) which provides authentication services for the rest of the SensorWeb services.

III. ADDITION OF CLOUD COMPUTING SERVICE TO SENSORWEB

It was discovered during our pilot efforts that in order to make a system like this functional, there were many performance issues. Data sets were large and located in a variety of locations behind firewalls and had to be accessed across open networks, so security was an issue. Furthermore, the network access acted as bottleneck to transfer map products to where they are needed. Finally, during disasters, many users and computer processes act in parallel and thus it was very easy to overload single strings of computers stitched together in a virtual system that was initially developed.

To address some of these performance issues, the team partnered with the Open Cloud Consortium (OCC) who supplied a Cloud Computing service. OCC provided hardware as shown in figure 3 along with manpower to administer this Cloud.

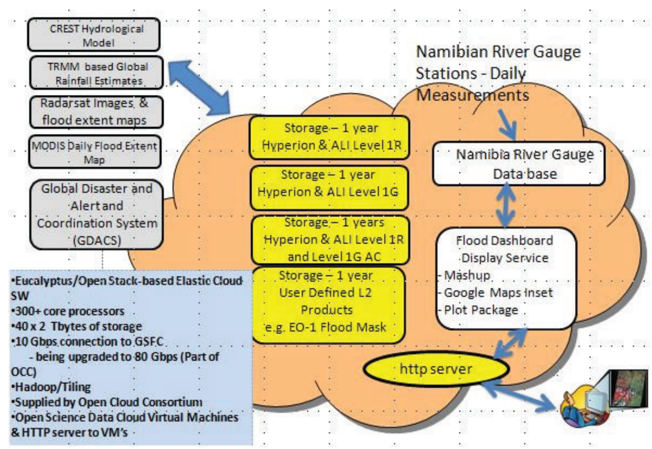

Fig. 3: Cloud computing service being used for Flood Pilot and some of the functionality that the team integrated

The Flood SensorWeb [3] system was interfaced to the Cloud to provide a high performance user interface and product development engine. Figure 3 shows some of the functionality integrated into the Cloud Service that was integrated. A significant portion of the original system was ported to the Cloud and during the past year, technical issues were resolved which included web access to the Cloud, security over the open Internet, beginning experiments on how to handle surge capacity by using the virtual machines in the cloud in parallel, using tiling techniques to render large data sets as layers on map, interfaces to allow user to customize the data processing/product chain and other performance enhancing techniques.

In essence, using Cloud terminology, OCC provide a Cloud with Platform As A Service (PAAS) functionality whereby they provided a computing platform stack which included an operating system, programming language execution environment and a web server. The team integrated a variety SensorWeb software and sensor data processing software thus to the disaster workers such as those at the Namibia Hydrological Services, they see it as Software As A Service (SAAS) cloud since our team is providing various software services such as providing flood extent maps derived from raw satellite image data.

At the PAAS level, the group is working on tiling services together with a Web Map Service (WMS) to enable the navigation of large data sets. Figure 4 shows a diagram of this critically needed function.

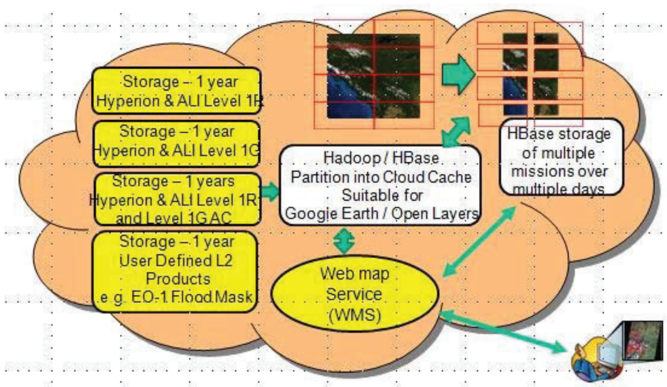

Fig. 4: Key function on the cloud is the use of Hadoop for tiling of large data sets

IV. Flood Dashboard

Our key data aggregation and display tool is the Flood Dashboard. The purpose of the Flood Dashboard is to provide a visual interface for users to access, mashup and visualize data products related to flooding to provide decision support. Figure 5 shows the Flood Dashboard top level display and can be accessed at http://matsu.opencloudconsortium.org/namibiaflood :

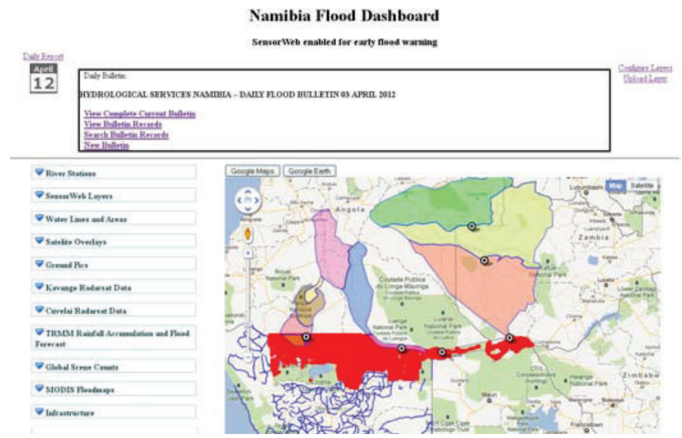

Fig. 5: Namibia Flood Dashboard with MODIS data layer, water lines and water catchments layer enabled

The Flood Dashboard provides the following capabilities and products at the time that this paper was written:

(1) MODIS water extent
(2) Radarsat water extent
(3) TRMM based flood forecast and rainfall accumulation (Adler NASA/GSFC)
(4) Earth Observing 1 experimental flood classification
(5) Selected river gauge hydrographs
(6) Catchment display layer
(7) Daily bulletin window that is actively used by Namibia Hydrological Services
(8) Global Disaster Alert and Coordination System (GDACS) overlay (Joint Research Center European Union) which models floods based on TRMM and AMSR-e and provides alerts to our system
(9) CREST Hydrological Model
(10) In-country infrastructure layer

One interesting feature of the Flood Dashboard is the auto-trigger function. For selected user areas of interest, there are upstream areas for which GDACS will issue alerts when river widths exceed a certain threshold. The Flood Dashboard in turn automatically tasks Earth Observing 1 (EO-1) at the downstream locations. This is done because for EO-1 and other higher resolution satellites, it takes up to 3 days for EO-1 to be in view of a selected area. Often times, when a flood occurs, tasking EO-1 at the time of an observed flood might be too late. This provides the system the ability to anticipate a future flood since the hydrologists for the Namibia Hydrological Services know how long it takes a flood wave to travel downstream. In many cases, floods in Angola task 5 to 10 days to arrive in Namibia.

V. SCIENCE AS A SERVICE

The ultimate goal of the combination the Flood SensorWeb and the Computation Cloud is to provide the equivalent of Software As A Service (SAAS) in which higher level software functionality is provided to the user without the need for software skills. By virtualizing the access to sensor data and the controls for how the data is processes and delivered, the SAAS can mean Science As a Service which is Software As A Service focused on the Science and the Applied Science disciplines. These virtualized support services provide scientists and disaster managers tools to make more efficient and rapid use of remote sensing date thus lowering cost for these activities. Users are provided with tools for improved situational awareness and in addition, there are tools to experiment with new ways to use the data and tools to validate data products.

For example, at present, one of the key activities of interest for the hydrologists in Namibia is to validate the water extent product produced from Radarsat data. They want to assure that when the product specifies water at a location, it is actually there. Thus one of the capabilities that is being developed is a crowd sourcing capability in which other observers of the data can modify the polygons for the water extent based on GPS observations made on the ground. Inputs are provided to the cloud via cell phone or Ipad and interoperate using Open Street format. Figure 6 shows a preliminary experiment with an automated water extent product derived from Radarsat that is displayed on an Ipad. It is a tiled display so that that the user can zoom in and ultimately manipulate the polygons or at minimum place a pushpin on the map showing actual water locations from the ground observations. Each pushpin would have various metadata to label the type of person doing the observing. For example, when modifying the water mask, the hydrologists may only want to use the observation of other hydrologists or designated people. However, if an area is remote and no other observations are available, the user may want to accept observations from unknown people if there is nothing else. Figure 6 shows a test Radarsat automated tiled water extent display on the cloud and also available on the Ipad. One of the challenges was shipping the tiled display to the Ipad.

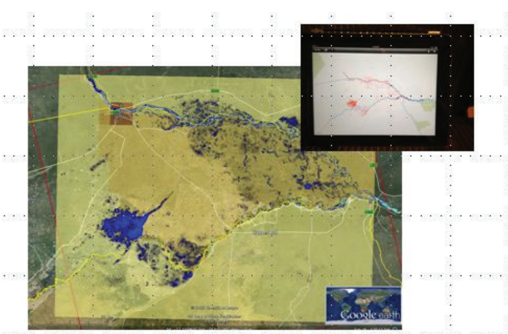

Fig. 6: Radarsat automated tiled water extent display along with corresponding Ipad display

VI. FUTURE DIRECTION FOR EARLY FLOOD WARNING SYSTEM

Some of the developers for the Namibia Early Flood Warning system traveled to Namibia in January 2012 to meet with the Namibia Hydrological Services and determine how to build future capacity for Namibia. Given limited resources for this research, a priority list was created of activities and functionality that are the most valuable. The top activities that the group will focus on are as follows:

(1) Simultaneous tasking of EO-1 and Radarsat

(2) Develop an Application Programming Interface (API) to provide the user a Web Coverage Service (WCS) for Radarsat data and water extent product, thus being able to specify an area of interest visually and obtain what is in that area

(3) Develop an automated Radarsat water extent algorithm that runs on the Cloud

(4) Develop a better higher resolution hydrological model – long term goal

(5) Provide training to Namibian hydrologists on Radarsat processing and hydrological model development – long term goal

VII. CONCLUSION

The prototyping and capacity building effort on the Namibian Early Flood Warning system which consists of SensorWeb components and Cloud Computing services, support the goals of the CEOS Working Group on Information Systems and Services (WGISS) work. It especially addresses some of the aspects for developing an international disaster architecture which is the focus of some of the work in the WGISS group.

REFERENCES

[1] Frye, S., Mandl, D., "Overview of Namibian Flood/Disease SensorWeb Pilot Project", IGARSS 2009, Cape Town, South Africa, July 12-17, 2009

[2] Mandl, D., "Matsu: An Elastic Cloud Connected to a SensorWeb for Disaster Response", GSAW, Session 12F Working Group: Cloud Computing for Spacecraft Operations March 2, 2011 Los Angeles, CA

[3] Mandl, D., Rob Sohlberg, Chris Justice, Stephen Ungar, Troy Ames, Stuart Frye, Steve Chien, Pat Cappelaere, Daniel Tran, Linda Derezinski, Granville Paules, "A Space-based Sensor Web For Disaster Management", IGARSS 2008, July 6, 2008, Boston, MA

[4] GEOSS Architecture Implementation Pilot http://www.ogcnetwork.net/AIpilot

[5] Group on Earth Observations (GEO), GEOSS AIP Architecture – GEOSS Architecture Implementation Pilot (AIP), 28 February 2012 http://www.earthobservations.org/documents/cfp/201202_geoss_cfp_aip5_architecture.pdf

[6] CEOS WGISS GA.4.Disasters Project, http://tinyurl.com/GA4Disasters