TOWARDS A SENSOR WEB ARCHITECTURE FOR DISASTER MANAGEMENT: INSIGHTS FROM THE NAMIBIA FLOOD PILOT

Stuart Frye
Stinger Ghaffarian Technologies, Inc.
Greenbelt, MD, USA
stuart.frye@nasa.gov

Karen Moe, Dan Mandl, Matt Handy
National Aeronautics and Space Administration
Greenbelt, MD, USA
{karen.moe, dan.mandl, matt.handy}@nasa.gov

George Percivall
The Open Geospatial Consortium
Wayland, MA, USA
gpercivall@opengeospatial.org

John Evans
Global Science & Technology, Inc.
Greenbelt, MD, USA
john.evans@gst.com

ABSTRACT

The Group on Earth Observations, GEO, has identified the need to improve disaster risk management by providing timely information relevant to the full disaster management cycle of mitigation, preparedness/warning, response and recovery. The Committee on Earth Observing Satellites, CEOS, as the satellite arm of GEO, has recognized the important role that remote sensing contributes to all phases of the disaster management cycle. Activities to address the satellite information needs and gap analysis for disaster management systems are ongoing. This paper reports on results from two such activities, the southern Africa Flood and Health Pilot addressing annual floods in Namibia, and the GEOSS Architecture for Disasters analysis to enhance the use of satellite data. Direct interaction with Namibian hydrologists to experiment with satellite and in situ data products has helped inform the disasters architecture, providing lessons learned and best practices for the GEO societal benefit areas.

Keywords—GEOSS, GEO, CEOS, Disaster Management, Earth Observations, Sensor Web, Interoperability, Architecture, Namibia, Crowdsourcing

I. INTRODUCTION

Earth observations provide vital information for the management of disasters [1], allowing for the reduction and mitigation of risk, and enhancing response to, and recovery from, disaster events. However, particularly at regional and global scales, the use of these data in addressing disasters is often hindered by difficulties in coordinating joint activity among many organizations (international, national, and local) and by the complexities of drawing on many information resources with widely varying quality, formats, definitions, and access policies. [2, 3]

The Committee on Earth Observing Satellites (CEOS) Working Group on Information Systems and Services [4], in partnership with the Group on Earth Observations (GEO) Disasters Societal Benefit Area (SBA) [5], aims to address these challenges, and to enhance the capabilities of the Global Earth Observation System of Systems (GEOSS) [6] for decision makers engaged in disaster management and risk assessment. We describe here two CEOS/GEO activities intended to guide the application of earth observations – whether from satellites or from other sensors, models, or archives – to disaster management. First, a pilot project known as the Namibia Flood Sensor Web Pilot illustrates how these resources may be applied in a practical, real-world setting. Second, a reference model generalizes from this and other experiences to characterize the disaster management lifecycle and processes as a whole, and to sketch the role of satellite and other data in enhancing these processes.

II. THE NAMIBIA FLOOD SENSOR WEB PILOT

The Namibia Flood Sensor Web Pilot is an international collaboration under the auspices of Committee on Earth Observation Satellite (CEOS) Disasters team. In each of the past three years, a team from the US National Aeronautics and Space Administration (NASA) has traveled to Namibia to work with local counterparts towards the infusion of satellite and ground sensors into a sensor web to assess flood damage and provide early flood warnings.

Sensor webs are groups of sensors linked by an information fabric that virtualizes access and control of the sensors and allows the sensors to behave in a coordinated manner. Sensor webs rely on standards, in particular the Open Geospatial Consortium (OGC) Sensor Web Enablement suite of web service standards. Figure 1 depicts the high level architecture for Sensor Web.

Broadly, this collaboration with users in the field aims to articulate information needs and to develop and apply prototype technologies, standards, and practices. More specifically, the NASA team has used flood disasters as a path finder to develop Sensor Web capability enabling users to discover sensors (especially space based sensors) and make them searchable on the Internet; to customize and automate data products drawing on multiple sensors; and to provide data feeds and tools that let non-technical users customize data products and task available sensors.

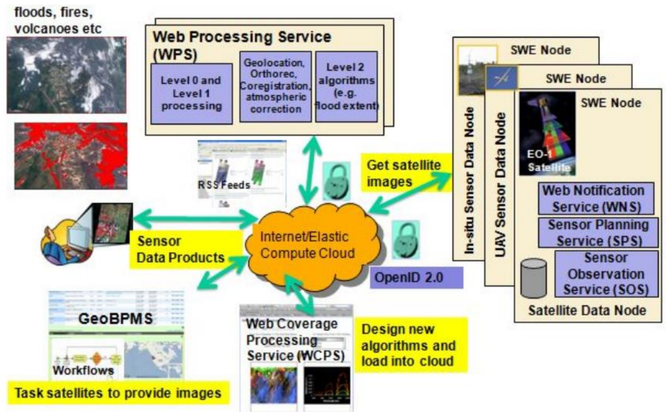

Figure 1. Basic Sensor Web architecture

The focus of the team's most recent trip, in January 2013, was integration of the sensor web with the OpenStreetMap (OSM) standard [15] and corresponding ground data to validate satellite data in an automated and efficient manner. OpenStreetMap is a collaborative international project to create free, editable maps of the world. Thus it enables groups to share mapping information in a low cost inter-operable manner. The team is combining Sensor Web and OSM functionality to create a shared database for water based information in which water contours are tagged with data source, normal *vs.* flood water, ground GPS contour, low and high seasonal water levels, and other tags. Thanks to these tags, users will be able to query the database for water contour information based on selected criteria.

One of the key uses of this approach is to correlate ground truth points (*e.g.*, the actual location of water boundaries) with satellite remotely sensed water locations. During the past couple of years, it was noted that water detection algorithms based on RADARSAT [16] and Earth Observing 1 (EO-1) [17] images did not always accurately detect water locations. For example, customary detection algorithms tend to show water in the presence of reeds as dry land. For decision makers in flood disasters, this is a crucial difference, and greatly affects the utility of remote sensing.

Our most recent pilot focused on the Kavango River in the north part of Namibia. Our methodology was as follows: Sensor Web software generated GeoTIFF images derived from RADARSAT and EO-1 data and automatically convert-ed these into a tiled OSM vector-based display. Each RADARSAT and EO-1 scene was cut into 9 to 27 tiles due to size. Each of several ground (boat) teams would determine the tile corresponding to their geographic location and import the corresponding RADARSAT OSM display into the Java Open-

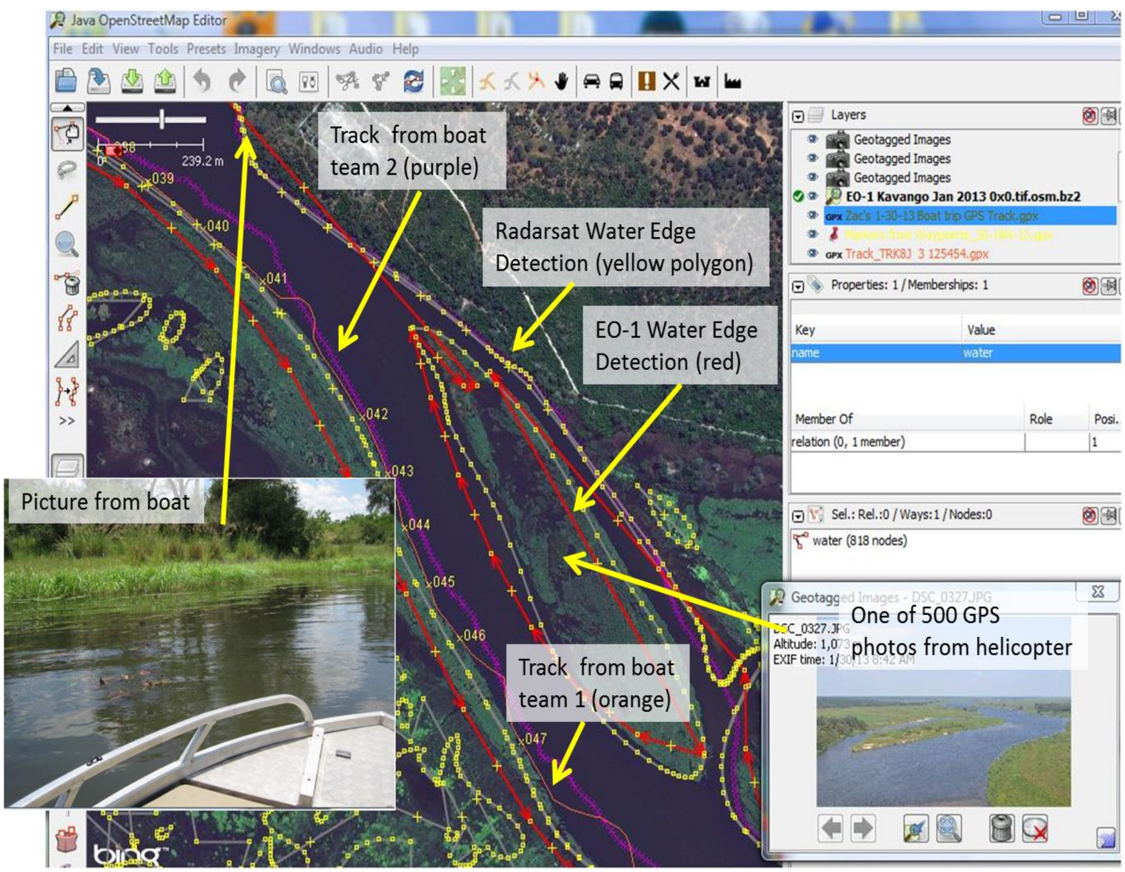

Figure 2. Field validation of RADARSAT and EO-1 water boundaries

StreetMap (JOSM) editor. They then tagged water contours visible in these images, and exported them into a relational database. Using GPS in the field, teams generated ground vectors and imported these into JOSM; tagged them as ground truth; and noted any discrepancies with the RADARSAT and EO-1 detections. Figure 2 illustrates this process.

The process for correcting the detection of water by the algorithms is now being discussed with in-country hydrologists, with results to be outlined in a subsequent publication. In the future this exercise will lay out a streamlined process for using OSM and Sensor Web, with a Flood Dashboard and a cloud-based database. (Figure 3)

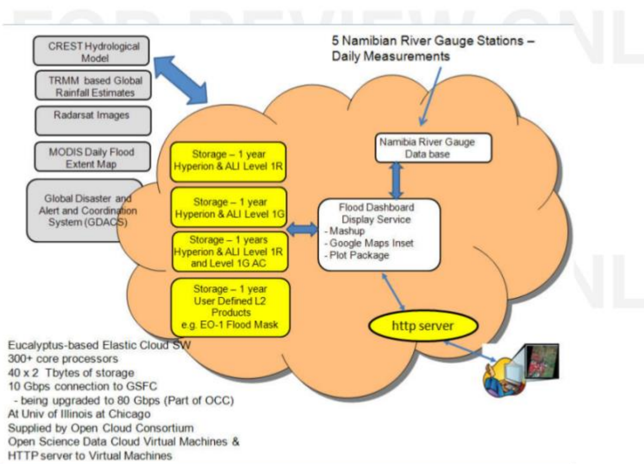

Figure 3. Computation Cloud integrated with Flood Sensor Web

III. Architecture Description

Drawing on insights from the Namibia Sensor Web Pilot and several other experiences, we are devising a reference architecture for the use of earth observations in disaster management, based on the ISO/IEC Reference Model for Open Distributed Processing [7]. This architecture provides a shared, structured description of the scope, policies, information types, and service categories that comprise the GEOSS disaster management and risk assessment enterprise, and it enables new users to ascertain more quickly what information or computing resources are available and how to gain access to them. It also allows new suppliers of such resources to grasp more easily how and where their contributions can best be put to use.

This architecture is practice-based; but it also draws on work by the GEOSS User Interface Committee [8] and the CEOS Disasters SBA [9] to frame the overall scope, policies, and purpose of the activities and systems involved. This two-pronged approach helps users, providers, and planners work together to enhance the supply of satellite and other data to disaster management [13].

IV. Architecture Analysis

The architecture, and the practitioner experiences that it drew on, suggest several recommendations for suppliers of data, systems, or services, aimed at streamlining and broadening access to space- or ground-based earth observations; model results; or archived baseline data such as terrain models. Based on examination of the case studies, Figure 4 captures the suite of high-level activities needed to operationally monitor, detect, and respond to disaster events. These activities can be grouped into five broad service types: event detection, situational awareness, data acquisition (including sensor tasking for in situ and remote sensors), modeling, analysis / interpretation, and dissemination of a wide variety of products to users.

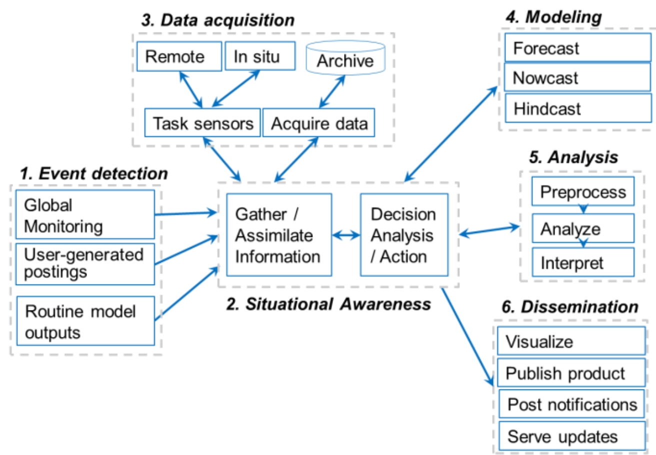

Figure 4. Key Activities in Sensor and Satellite Support to Disaster Management

These activities show the role of a variety of sensing products, including space-based and in situ sensors, user contributed near real-time information as well as models in contributing to the situational awareness of an unfolding event and the resulting analysis products intended to support disaster responders.

The case studies [14] offer insights and suggest priorities for many different participants in the disaster management lifecycle, from event response to longer-term recovery, impact mitigation, risk assessment, and hazard prediction. Recommendations include easing restrictions on data distribution; favoring open over proprietary or ad hoc service interfaces; and characterizing the diverse and dynamic needs of end users at the various stages of the disaster management lifecycle.

V. Conclusion

This paper described key findings regarding the use of satellite data and its integration with in situ sensing data and modeling products in support of disasters and risk assessment. The architecture results are based on several case studies however the Namibia Flood Sensor Web illustrates the role of in situ measurements to calibrate the space radar data. The challenges faced by the Namibian hydrologists in using the satellite data products points to the need for customizable data products that can take advantage of sparse but accurate in situ measurements. Future applications of satellite observations for the GEOSS societal benefits can profit from the lessons learned and captured in the disasters management architecture.

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