Integrated Risk Management in South Africa: Between Technological Features and Organizational Reality

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Abstract: Despite many international and local initiatives on disaster risk management and advances in scientific knowledge, the social and economic impact of natural disasters in emerging and developing countries is still increasing. Various activities are under way to investigate the potential of counter measures and mitigation strategies to handle the growing number of natural disasters. In June 2008, the European Commission initiated a new research project to demonstrate the capacity of standardised low cost interoperable information and communication technology (ICT) solutions to effectively mitigate disaster risk by addressing all phases of disaster risk management from risk assessment to recovery; paving the way to improved risk governance and contributing to sustainable development. This paper will present the first results from a South African perspective, which provides an interesting insight on the major challenges ahead, where technological progress meets organizational reality. It illustrates the current situation in South Africa in the context of governmental instruments and organization to support disaster risk reduction and disaster management and sheds light on our recent achievements in scientific workflows for disaster management research. A flooding scenario is used to demonstrate the functionality of scientific workflows. The paper concludes with an outlook how the entire risk management environment can benefit from them.

Keywords: Risk Management; natural disaster, information technology; scientific workflow; floods; South Africa.

1. Introduction

There is growing evidence that the number of hazardous events is continuously increasing worldwide, even though there are some difficulties comparing the last thirty years with, say, the beginning of the last century. The reporting wasn't as thorough as it is today, where the media echo has increased during the last decades and reporting frequency and efficiency has improved. Nevertheless, figure 1 gives a clear picture of ongoing development: The number of events is continuously increasing. Among those events, 80% of natural disasters are weather related (see figure 2). Floods are the most critical hazardous events with regard to loss of life and injuries, followed by tropical cyclones, storms, tornadoes, gale, heavy rain, thunderstorms, cloudburst, hailstorm, and bush fire.

It is moreover, important to recognise the causal connectedness among disasters. Floods, for example, can lead to loss of life, infrastructure, environmental, and agricultural resources. This, in turn, can lead to increases in disease vulnerability, loss of livelihood, property and food shortages, which again, compound the effects of other disasters. Clearly, the impact of disasters is experienced on a much wider spatio-temporal scale than just around the event itself. As supported by climate change research, there is a complex and compounding interaction among co-occurring disasters at very diverse temporal and spatial extents. The impact of a flood or earthquake is immensely more devastating in regions of rising poverty and desertification. Africa is most at risk in this context.

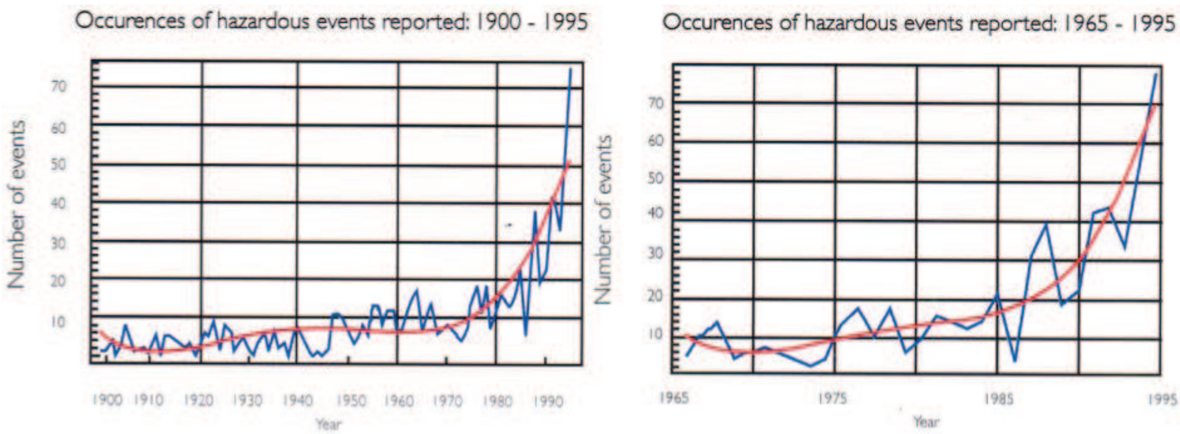

Figure 1: Hazardous events reported in South Africa 1900-1995 [1]

Although the distribution of disasters varies from Northern to Southern Africa (see figure 2), the connectedness among disasters remain. It is therefore essential to address disaster risk management in a coherent, multisectoral, multidisciplinary and integrated manner, along the entire spatio-temporal trajectory preceding and following an event. It is also necessary to consider the complete life cycle of a disaster, from prediction to mitigation along all its aspects. These dimensions include the technical, procedural, political and socio-economic.

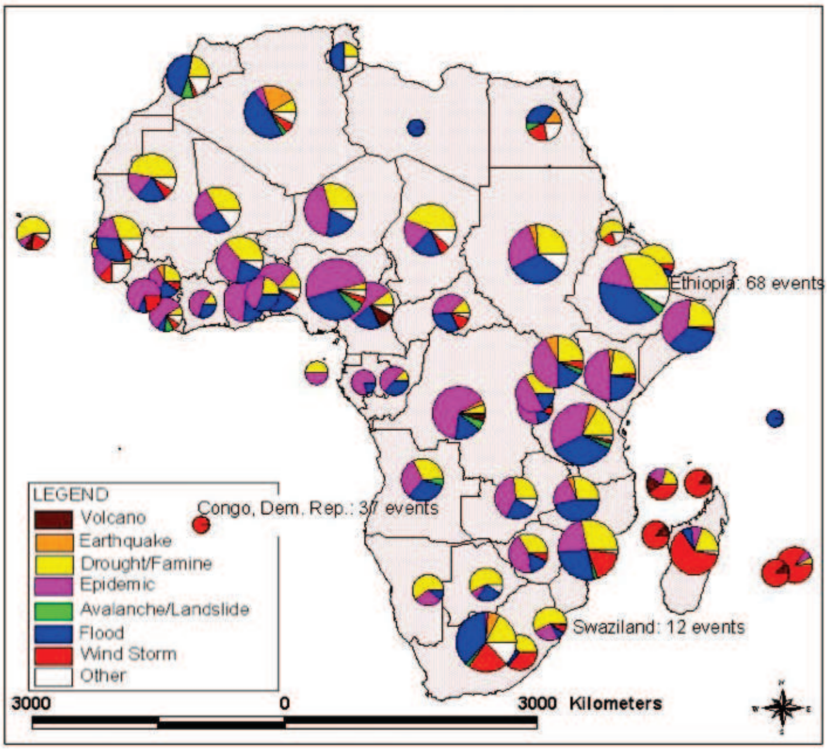

Figure 2: Distribution of natural disasters, by country and type of phenomena, in Africa (1975-2001) [2]

Despite many international and local initiatives on disaster risk management and advances in scientific knowledge, the social and economic impact of natural disasters in emerging and developing countries is growing. Various activities are under way to investigate the potential of counter measures and mitigation strategies to handle the growing number of natural disasters. In June 2008, the European Commission kicked-off a new collaborative research project called "Integrated Risk Management for Africa (IRMA), to demonstrate the capacity of standardised low cost interoperable information and communication technology (ICT) solutions to effectively mitigate disaster risk. It addresses all phases of disaster risk management from risk assessment to recovery; paving the way to improved risk governance and contributing to sustainable development. It is funded as part of the 7th Framework Program; thread Information and Communication Technology for Environmental Management and Energy Efficiency.

This paper will provide a short overview of the methodology applied in and the goals of IRMA in the next section, as the findings documented in this paper have been developed in the context of this project. The remainder of the paper is structured as follows. The third section illustrates the current situation regarding disaster management in South Africa and presents our first results achieved in the context of IRMA. The main challenges are illustrated in section four. Section five discusses technological improvements for disaster management and explains our scientific workflow approach, that is further illustrated in section six using a flood-monitoring scenario. A summary of our results is provided in section seven, which concludes this paper.

2. Integrated Risk Management in Africa - IRMA

Integrated Risk Management in Africa (IRMA [3]), is a Specific International Cooperation Action (SICA) in ICT for environmental disaster reduction and management, the assessment of natural hazards and communities vulnerability together with the development and interoperability of rapidly deployable ICT-based solutions for public warnings and emergency management. It is co-funded by the Information Society and Media DG of the European Commission. For the duration of 36 months, it brings 15 partners (nine from Europe and 6 from Africa, located in South Africa, Senegal, Morocco, Cameroon, and Mozambique) together with the goal to build a reference platform suitable for the management of natural and environmental risks in Africa. The platform must allow the stakeholders in risk management to develop and use tailored risk management models and tools; therefore, the platform will be build upon the achievements of former EU projects as there are interoperable components, information infrastructure architectures and solutions, as well as clients and management tools and frameworks that allow to set up an efficient and sustainable multi-risks management.

The platform will feature two major technical components: A Web service environment and a state-of-the-art IPv6 network infrastructure. The Web services will be used for the exploration, acquisition, processing, decision-support, and dissemination of information. Those services will be combined with an efficient storage of all relevant information. IRMA will apply the principles of Spatial Data Infrastructures (SDI) to achieve a set of distributed interoperable components. The components provide interfaces compliant to international adopted standards and specifications, such as those developed by the Open Geospatial Consortium (OGC), the World Wide Web Consortium (W3C), the Organization for the Advancement of Structured Information Standards (OASIS), and the International Organization for Standardization (ISO). The interoperable access and the permanent provision of past and current data does not only improve the disaster management during the course of operation, but it allows stakeholders to analyse afterwards the sequence of events and adapt operational procedures consequently. Wherever possible, IRMA will install a multi-purpose solution for the communications based on IPv6 either to federate legacy communications or to provide native IPv6 solutions.

The project intends to deliver a pre-operational open infrastructure and access-platform, assessed by end-users in operational scenarios. Those scenarios serve as references for a future larger scale deployment of the platform and its components. Further on, the platform provides the facilities for prototyping risk management systems and for supporting a rapid development of applications services. Specific applications (Bushfire, Flood, Desertification and urban risks) will populate this platform during the project. This paper illustrates the first results produced in the context of IRMA.

IRMA starts with an in-depth analysis of the existing risk management scenarios for the selected hazards in the contributing countries in Africa. The analysis will cover the whole risk management cycle but focusing on the one hand on the current information flow between entities involved, on the other hand on lower level information services that are or could be made hazard independent. The objectives being first to achieve a smooth integration of all risk management phases, second improve the re-usability of services. The next will design service oriented architecture to be implemented progressively by adopting a system of systems approach. It will start with a review of recent research project results, the analysis of existing services made available by international organisations such as Relief Web provided by the UN or GDACS provided by the DG JRC, or currently available free and Open Source software such as the Sahana software suite to support humanitarian disasters. The architecture aims at a smooth integration of all those partial solutions. In the progress IRMA, we will develop the missing bits and pieces of interfacing middleware and selected risk management services set up a telecommunication sub-system needed to support early warning, alert and emergency response messages. All developments will be tested in pilot applications eventually. The entire project is accompanied by dissemination activities with focus on training and human capacity building events and activities.

3. Disaster Risk Reduction in South Africa

On a global scale, 46 countries have developed national mechanisms for disaster risk reduction (DRR) that fully subscribe to the standard UN guidelines on national platforms (figure 3). Those mechanisms are shaped as networks of institutions are even networks of networks, and fulfil a number of technical, operational, legal, political, and strategic functions. Among the more technical oriented functions, the national mechanisms provide hazard assessments, mapping, analysis and related training and education, identification of vulnerability factors and their assessment, and disaster prediction and early warning. On the more political, legal, and strategic functions, the relevant functions are the development of policies and regulations for decision makers, the development of human and technical capacities, enforcement of regulations and plans, and accompanying research and development.

Although many more countries have disaster risk reduction mechanisms applied, they usually lack multi sectoral or multi disciplinary characteristics. The growing number of countries converging the UN guidelines more seriously and improving their DRR mechanisms is an indicator for a growing recognition among national authorities. In Africa, a number of countries have developed detailed and strong disaster risk reductions policies and plans, with South Africa, Uganda, Mozambique, and Senegal among them. Further on, a growing cooperation between international organizations, such as the UN global development network UNDP (United Nations Development Programme), the International Federation of Red Cross and Red Crescent, which develops tools such as the Disaster Management Information System (DMIS), a web-based tool for their own personnel including disaster trends, tools and databases, the World Meteorological Organization (WMO), or even the United Nations Office for Outer Space Affairs (UUOSA) can be identified. Still, the formation of institutions and the layout of plans is a first step. Legal structures have to be promulgated and institutions operationalized to fight volatility of those structures.

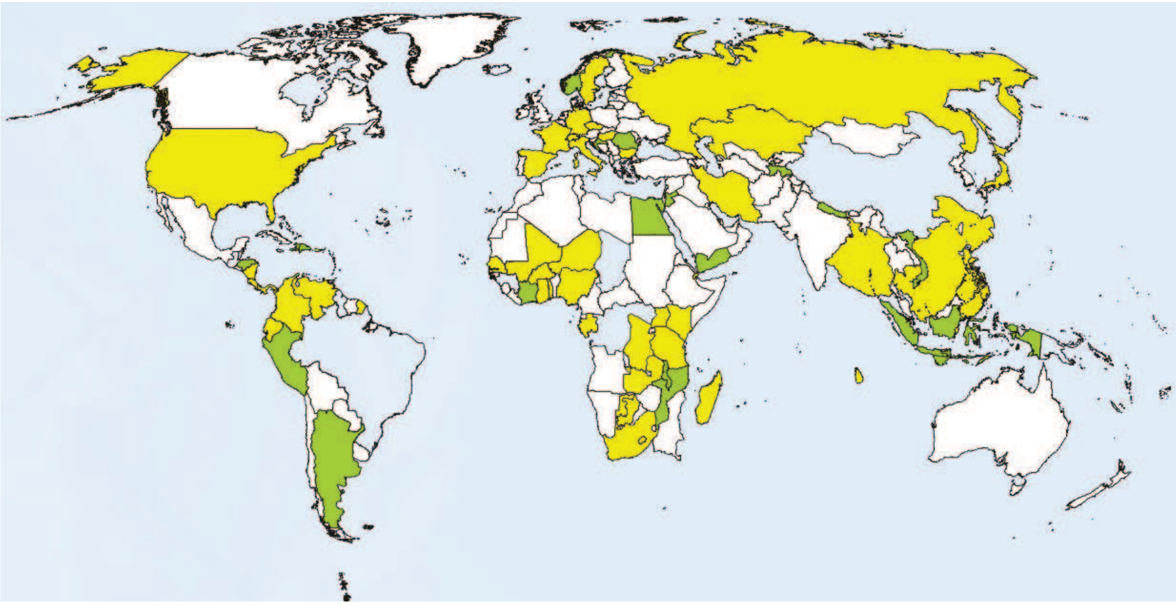

Figure 3: Countries with national mechanisms for DRR (yellow) or countries in the process of establishing (green) [4]

South Africa national mechanism has been put in action by establishing three forums:

- Intergovernmental Committee on Disaster Management (CDM), established by the president and staffed by cabinet members involved in disaster management or the administration of legislation, representatives of the provinces involved in disaster management, and representatives of organized local government, selected by the South African Local Government Association. The CDM advises the cabinet on issues relating to disaster management; and on the establishment of a national framework for disaster management aimed at ensuring an integrated and uniform approach to disaster management by all national, provincial and municipal organs of state, statutory functionaries, non-government institutions involved in disaster management, the private sector, communities and individuals [5].
- National Disaster Management Advisory Forum (NDMAF), staffed by the head of the National Centre for Disaster Management, senior representatives of each national department whose Minister is a member of the CDM, regional governmental representatives, and big number of representatives from various groups and shades. The Forum is therefore, the body in which national, provincial and local government and other disaster management role-players consult one another and coordinate actions on matters relating to disaster management. The forum's key responsibility is to make recommendations concerning the national disaster management framework to the Intergovernmental Committee on Disaster Management. Furthermore it may advise any organ of state, statutory functionary, non-governmental organization or community or the private sector on any matter relating to disaster management.
- Disaster Management Institute of South Africa (DMISA), a non-profit association for disaster management professionals in Southern Africa primarily aiming at learning and networking opportunities for its members.

South Africa has promulgated the Disaster Management Act (Act 57 of 2002) in 2002 and put into action with its publication on January 15, 2003. The act focuses on disaster prevention and risk reduction; mitigation of severity and consequences of disasters; emergency preparedness and effective response to disasters leading to restoration of normal conditions [1]. It is a legal mandate to establish a national disaster management framework under which national, provincial and municipal disaster management centres should be implemented [5]. The National Disaster Management Centre (NDMC) has been established to this end, promote an integrated and coordinated system of disaster management, focussing on prevention and mitigation by national, provincial and municipal organs of state and statutory functionaries. While significant strides have been made in achieving a level of implementation and operationalisation of the Disaster Management Act, nationally and provincially, there has been a limited success at the municipal level. The latter region, paradoxically, would be the first affected and responder in an event.

The Disaster Management Act specifies the legal instrument "National Disaster Management Framework" to address disaster management needs consistent across multiple interest groups. The national disaster management framework complies with international best practices in putting explicit emphasis on concepts of disaster risk management for disaster prevention and disaster mitigation. It also serves as the basis for provincial and municipal frameworks and plans to ensure and guide action across all spheres of the Government.

4. Challenges for Disaster Reduction in South Africa

Disasters are not confined to national borders and a supra-national system would facilitate a more effective response. While there may be global and continental coordination at the political and socio-economic levels, there is little evidence that much coordination has been achieved at the technical and infrastructural levels. Resources such as sensing systems and information and communication platforms are primarily applied in 'stove-pipe' fashion by countries and sometimes, within countries. Many resources have been mobilised in an isolated manner for disaster response and relief; in 2006/7, billions of rand have been invested by three countries alone for only six disastrous events in Africa [1].

For Africa, being generally recognised as the poorest and most vulnerable continent for extreme weather conditions due to climate change, the sharing of resources and integration of systems would hold major benefits. There exist several challenges for disaster management in Africa, most notably:

- **A poor record of disaster risk research and development**: To date, most research on disasters have been conducted in and led by developed countries, with consequent weak capability to plan, implement and maintain disaster risk management systems suitable to African conditions

- **Poor data acquisition**: Access to, and use of particularly space based sensory information have been sparse at best, with some African countries dependent on purchased, archived and historical data resources

- **Dependence on archaic tools and infrastructure**: Lack of funding and capacity impact on many other barriers mentioned, but its consequence is most visible in the application of ICTs that are out of date and less effective than modern day implementations

- **Uncoordinated and 'stove-pipe' development**: Activities have largely been confined to isolated implementations, leading to incoherent, fragmented and duplicated investment. While there have been recent initiatives at coordination among African countries (e.g., SPIDER in Africa), the outcomes of these activities have yet to percolate down to operational levels

Interoperability is key to the integration of information and communications technology systems, and largely determines the extent to which resources can be shared amongst such platforms. Interoperability can be realized only when role players (a) collaborate and share resources and (b) are aware of ICT efforts and activities beyond an isolated and specific case of application. Standards, recommendations and best practices, as promoted by the Group on Earth Observations (GEO), are primarily intended to enable interoperability [5] among software tools and data products. The objective, together with the Global Earth Observing System of Systems (GEOSS) initiative, is to provide shared and distributed products that are useful for addressing challenges in nine thematic Societal Benefit Areas. [7, 8]

One such area is Disasters, and a number of products in the form of components and services have been developed and contributed to the GEOSS Common Infrastructure (GCI). The ICT for Earth Observation research group (ICT4EO) at the Meraka Institute is actively participating in activities of the Open Geospatial Consortium, an affiliated organisation of GEO. Together with other organisations globally, ICT4EO are addressing technology challenges pertaining to data product access and community practices for disaster response as contributions to the second phase of the Architecture and Implementation Pilot (AIP2). Their participation in the Sensor Web Enablement and Capacity Building Task is intended to promote the use of open and shared ICT infrastructures, with focus on disaster risk management.

5. Technological Improvements for Disaster Reduction in South Africa

The ICT4EO group together with the School of Computer Science at the University of KwaZulu-Natal are currently developing an integrated distributed computing platform for disaster management. The Scientific Workflow for the Sensor Web (SW4SE) platform [9] aims to provide a computing infrastructure for developing and deploying disaster management monitoring and alerting applications as well as an environment to aid earth observation scientists to conduct research on the causes and impact of disasters.

The platform incorporates two key technologies. Firstly, the Open Geospatial Consortium’s (OGC) Sensor Web Enablement (SWE) [10] platform provides a framework for deploying and accessing earth observation data and processing services. Secondly, a scientific workflow framework, (SW4SE) [9] is used to develop and assemble the complex processing chains that connects data sets, processes and prediction models to extract meaningful information for decision makers to better plan for and manage disasters.

Many scientific advances are achieved through complex and distributed scientific computations that are increasingly being undertaken over the Internet. A workflow environment provides the mechanisms to execute these tasks. Each task can be a data acquisition, transformation, computational, analytical, publication process, or a workflow sub-process in its own right.

Scientific workflows play a critical role in e-science [11], since scientists use them to automate and manage the steps needed to generate scientific discovery from raw datasets. Scientific workflows can integrate vast numbers of diverse data sources and can execute individual processing applications in a highly distributed environment. Such an environment provides for a collaborative design process that may involve many scientists across disciplines and across geographically dispersed locations. A scientist must not only be able to compose, execute, monitor, and re-run large-scale data-intensive and compute-intensive scientific workflows, but also use them to reproduce scientific discovery [12].

Earth observation scientists, specifically those that research natural disasters, collect process and analyse vast quantities of heterogeneous data, with new data continuously being generated. In the typical case, data and associated transformation and analysis processes are used to generate results which are accessible only to the scientist carrying out the investigation. SW4SW not only presents a means for generating such knowledge more formally, but also facilitates the sharing of the data, processes and knowledge in a controlled and collaborative manner. This is especially important for developing countries, that can leverage the vast satellite data repositories and expertise available in developed countries

Typically a Sensor Web architecture [10, 13] consists of web accessible services or sensor resources that provide sensor data, simulation and predication models, and processing services. Figure 4 shows a high level conceptual architecture for the SW4SW platform currently being researched within the ICT4EO group. Earth observation data providers in developed countries, such as ESA and NASA, publish their data sets, such as satellite-based remote sensing imagery, via sensor data services. Earth observation researchers present their algorithms, e.g., image processing or data analysis as processing services on the Sensor Web. These services take in appropriate data, perform the required processing and return the results to the user. Interactive modelling services that encapsulate simulation or predication models are also made available to users. Researchers are able to publish derived datasets, results, or new models back onto the Sensor Web. African scientists use the SW4SW platform to discover existing resources. They select the resources that they require and assemble these into workflows to solve their problems. Once these workflows have been completed, the results and the workflow are published directly on the Sensor Web and are accessible to the general scientific community. Scientists from developed countries are able to view these workflows and gain a better understanding of the problems facing the developing world. They are then able to use their experiences and expertise to improve on these workflows in collaboration with developing world scientists without being removed from the developing world context.

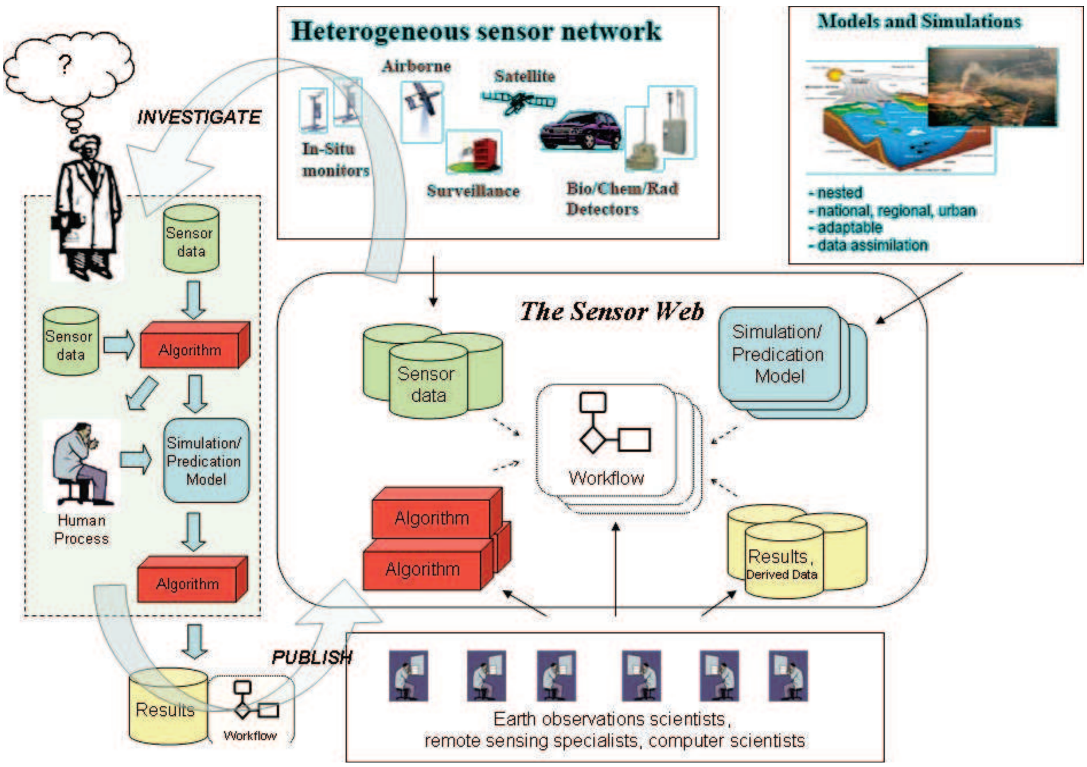

Figure 4: A conceptual framework for the SW4SW platform [9]

6. Using SW4SW for flood monitoring

The following scenario for flood monitoring [9] illustrates the use of the SW4SW platform for collaborative research on natural disasters. An African scientist wishes to explore the influence of topography, land use, climatic conditions and hydrological models for a given region, on flood risk prediction. She uses the Sensor Web to find resources that can assist her with this task and discovers hyperspectral data from NASA and MODIS data from the national Satellite Applications Centre (SAC). A remote sensing specialist (Researcher B) has also developed an algorithm that detects water levels from available satellite imagery. This algorithm can be applied to the hyperspectral and MODIS data. Researcher A is a data cleaning expert in her team and offers to clean the data. Researcher C at a European partner institute has published a suitable hydrological model that can be used for flood detection. The water level data, together with a Digital Elevation Model (DEM), and weather data from the local weather station is then supplied to this model. Figure 5 graphically depicts this situation.

Using catalogues, these resources have been discovered by the Sensor Web. She partially specifies required inputs and outputs and requests the workflow system to construct a possible workflow. The system records the workflow, schedules execution of processes, dynamically finds suitable resources, adapts the workflow to available data sets, and finally alerts other collaborating researchers to the results. The workflow and the new model are made available to collaborators and partner organisations, or are published for public consumption on the Sensor Web.

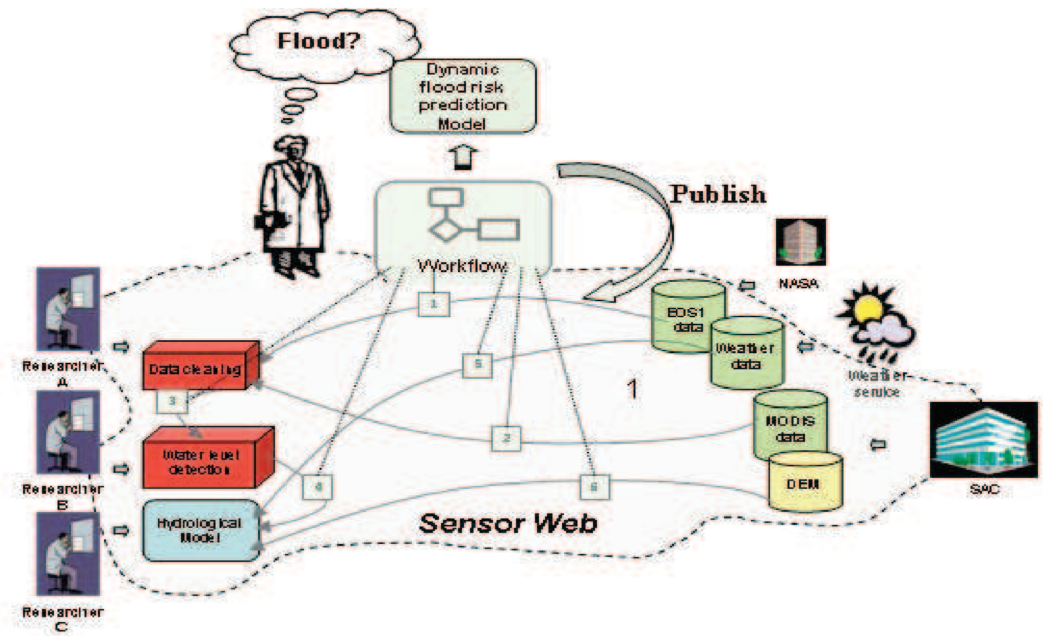

Figure 5: A SW4SW scenario for flood monitoring [9]

The major benefits of SW4SW [9] are anticipated as follows:

- **Platform to capture, share and integrate earth observation data and knowledge**: Sensor data, models and processes are shared and reused by scientists within and external to the earth observation community, providing individual scientists with easy access to timely and higher resolution data. Often, innovative models and processes published in traditional scientific literature are not easily reproducible, for a number of technical reasons. Publishing complex processes and models facilitates immediate reuse by other scientists within other processes or models. This is especially relevant for scientists from developing countries that can now leverage existing data and knowledge to better understand and manage natural disasters. Considering, the dearth of highly skilled African scientists, this knowledge provides a valuable resource that can be incorporated into teaching programs at academic institutions in developing countries to speed up their training of researchers.

- **Collaboration platform for multiple sites and organizations:** Scientists from different countries and different organisations are able to pool expertise and data and work together on large scale research projects, paving the way to undertake more complex research projects. Resources developed by individual researchers can be validated and tested by other scientists with alternate parameters or data and be republished. Resources developed at different partner organizations can be assembled into workflows to address complex problems, which can themselves be shared, executed with alternate resources, or incorporated into other workflows. Considering the amount of resources that the European Union has allocated for collaborative research between African and European institutions the platform can significantly enhance these collaborations.
- **Managing information overload**: Sensor data are being generated at rapid rates. Even though African Scientists have a deeper understanding of the local context, and are increasingly gaining access to data repositories available in the developed countries, they are often overwhelmed by the volume of available data and may lack the technical expertise and time to interpret all types of data. SW4SW can assist with this information overload. For example, a scientist could pose vague queries and the system can attempt to discover relevant data, processes and models that can assist with their task. In this way scientists can perform tasks without having expert knowledge of all data, processes and models stored in the system. Additionally SW4SW provides layers of abstraction that shield the scientist from the underlying complexity of the Sensor Web and allow for the generation of scientific knowledge in an environment that mirrors the processes in his/her domain.
- **Automated investigation and discovery**: SW4SW presents great potential for automating data analysis. When scientists pose queries to the system, there may not be an existing resource that satisfies the query. The system could identify potentially related resources, and use optimization and scheduling techniques to assemble resources into possible workflows that may satisfy the query. Machine learning techniques can be used to construct models from historical analysis of data and use these as a basis for predicting future events. Such models could be updated as new data becomes available. Intelligent agents can learn to find aberrant patterns prior to certain phenomena, e.g. detect unusual patterns of events prior to the occurrence of a flood. This knowledge can be used to discover new relations between phenomena and to derive improved prediction models.

7. Conclusions

Although we are still at a very early stage of the IRMA project, interesting results can already be supported. First the implementation of the disaster management act in South Africa on the municipal and partly even on the provincial level has by far not reached the standard of the national level. Lots of work is still required to implement the act where it is most needed. The IRMA project will further elaborate additional practices and strategies to improve the implementation process on the various spheres of Government. Yet IRMA's main activities will be applied to the technology sector. The experiments with scientific workflows have not only proven interesting technical results, but even work as an integration platform, as intense communication between the various players is an essential component. By this, scientific workflows seem to be perfectly suited to address the multi sectoral and multi disciplinary characteristics of successful disaster risk reduction and management. As the global community is continuously finding long-term solutions to disaster management, more effective disaster management can be achieved through collaborative and coordinated action. The outcomes of these efforts must cascade down to the operational level and there should be continuous feedback on the effectiveness of solutions. Africa should have an integrated approach for disaster risk management and should participate in global initiatives at sharing data and products, as well as general policies and procedures. Focus shall be laid on low cost, but high impact solutions within a short development period. Good severe weather forecasting is the priority for Africa, and require sophisticated solutions. Africa should develop capacity to plan, implement and maintain such systems in view of global change challenges.

Acknowledgements

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References

[1] DPLG (2007): National Disaster Management Centre. Inaugural Annual Report 2006/2007, Technical report, Department: Provincial and Local Government. Republic of South Africa.

[2] EM-DAT (2007): The OFDA/CRED International Disaster Database. http://www.cred.be

[3] http://www.irma.lu

[4] Martin Owor (2008): Strengthening national mechanisms for disaster management, South Africa Inaugural National Disaster Management Indaba, 2008, presentation

[5] DPLG (2003): Synopsis of the 'Disaster Management Act 2002'(Vol. 451 Cape Town 15 January 2003 No. 24252)

[6] Republic of South Africa, 'Disaster Management Act 2002'(Vol. 451 Cape Town 15 January 2003 No. 24252), Technical report, The Government of the Republic of South Africa.

[7] Group on Earth Observations (2008): The GEOSS Common Inifrastructure (GCI), http://www.earthobservations.org/, Accessed: 12 November 2008

[8] South African Earth Observation Network (2008) http://www.saeon.ac.za/

[9] Moodley D, Vahed A, Simonis I, McFerren G and Van Zyl T (2008). Enabling a new era of Earth observation research: scientific workflows for the Sensor Web. Ecological Circuits (1), pp. 20-23.

[10] Simonis, I. (2008): OpenGIS® Sensor Web Enablement Architecture Document, Open Geospatial Consortium, OGC 06-021r3.

[11] National E-Science Centre (2008): Defining e-Science, http://www.nesc.ac.uk/nesc/define.html (last accessed: 14 November 2008)

[12] Y Gil, E Deelman, M Ellisman, T Fahringer, G Fox, D Gannon, C Goble, M Livny, L Moreau and J Meyers (2007): Examining the Challenges of Scientific Workflows, IEEE Computer, Vol. 40, No. 12, pp. 24–32.

[13] Liang, S. & Tao, V. (2005): Distributed Geospatial Infrastructure for the Sensor Web Computers & Geosciences, 2005, 31(2), 221-231