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e-Infrastructure for Climate Adaptation Policies: the UNDP/AAP Activities

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Abstract: To effectively plan for adaptation to climate change and its impacts, decision makers require the infrastructure and tools that will provide them with timely access to current and future climate information. For example, climate scientists and operational forecasters need to access global and regional model projections and current climate information that they can use to generate climate products and services for multi-sectorial adaptation planning. Through the UNDP African Adaption Programme (AAP), an e- infrastructure capacity has been built across Africa that will provide multi-tiered access to such information and data for informed decision making. Web accessible servers provide both computational power and access to the information at many levels: including raw and processed climate model output, real-time climate conditions and products, knowledge products (technical documents and presentation) as well as decision support tools for decision and policy makers. In this paper we present (report and discuss) the results of a two-year activity in building such an e-infrastructure under the AAP program and the extensive technical support and services programme associated with establishing capacity across Africa.

Keywords: e-infrastructure climate change, climate data management, capacity building

1. Introduction

The United Nation Development Program (UNDP), with a funding of US$92.1 million from the Government of Japan, launched the Africa Adaptation Program (AAP), a three-year programme in 2009 to promote integrated and comprehensive approaches to climate change adaptation and disaster risk reduction in 20 countries in Africa. The project ensured that national development processes incorporated climate change risks and opportunities to secure development gains under a changing climate. UNDP helped countries to establish the enabling environment and develop the capacity required to design, finance, implement and monitor long-term and cost-effective adaptation policies and plans. The project completed in December 2012 with some transformational results already achieved.

One of the implementers of the AAP is the Inter-Regional Technical Support Component (IRTSC) that provides Inter-regional technical expertise and capacity development support to the 20 countries. The IRTSC assists in the early analysis and design of national projects and how those projects are being initiated and implemented. A key activity of the IRTSC is to facilitate access to the best available data and information on climate variability and impacts to support dynamic, long-term national planning and decision-making mechanisms. This is being achieved by providing assistance to countries

in accessing, collecting and analysing best available data on climate change and its impacts. In order to get this task realized there is a need to establish and build in-country and regional capacities on the development and management of e-infrastructure and its application to climate change studies and decision support tools for long-term adaptation planning.

The cost of acquisition and management of the appropriate computational infrastructure is so prohibitive that most developing countries cannot undertake on their own. Even when such infrastructure exists, the quality of power supply to sustain uninterrupted power for highly available ICT infrastructure, the technical expertise to manage such infrastructure and the enabling environment to ensure its effective operation are most often lacking.

Beyond the acquisition of computational infrastructure, access to robust climate scenarios and information on climate change and impacts, is the challenge of establishing the human capacity that will sustainably managed data and information management infrastructure as well as provide robust knowledge to inform policy and decision-making. There is, therefore, an urgent need to facilitate the acquisition and deployment of inexpensive high performance computational infrastructure and to build an African trans-disciplinary community of practice who are able to analyse climate data and apply decision support tools in multi-sectorial adaptation planning and decision-making.

To this end, the Data and Information Management Component (DIMC) of the IRTCS was established to support countries to establish the data and information management systems and processes and apply innovative technologies through the use of e-infrastructure (High Performance Computing, data, tools, methods and network of institutions).

The concept of e-infrastructure therefore provides a solution set and framework upon which the ICT/HPC infrastructure, data, decision support tools and methods and network of institutions are brought together in an integrated and comprehensive way to address a given climate change and development problem.

This paper provides the conceptual design of the AAP e-infrastructure and the program developed jointly by DIMC and its partners (the Italian team) to build capacities in countries to acquire, use and manage such infrastructure to inform the decision making process across Africa. It also describes the solution strategies adopted in over a two-year time frame to address both in-country and regional challenges. The knowledge products, best practices and sustainability of the legacies are also discussed. Also discussed are the challenges encountered and outlook for future work through on-going and future programming.

2. Objectives of This Work

The main goal of the work performed in the last two years was to develop and implement an e-infrastructure for the AAP programme across all the 20 AAP countries. Such platform gives access to the best available data and information on climate variability and impacts to support AAP countries in undertaking dynamic, long-term national planning and decision-making mechanisms. This will be achieved through the provision of technical assistance to countries in establishing the relevant mechanisms and infrastructure for accessing, collecting and analysing best available data on climate change and its impacts as well as using decision support tools for adaptation planning.

The challenge of deploying e-infrastructure distributed across 20 African countries and partner regional institutions required a combination of management and technical competencies as well as enabling environment that were not readily available within the AAP countries and had to be established through the initiative. Placing the solution strategy within the context of e-infrastructure enables bringing together all the ICT elements such as databases, servers and related infrastructure, data management and decision support tools and methods as well as the institutions to address the specific country problems. These

elements were then complemented/implemented by climate data harvesting and by a capacity building program, which constituted a fundamental part of the solution. The overall goal was therefore to setup a global computational environment, which embodies hardware, software and human resources tightly integrated

There are therefore different specific aspects, which contributed to the final success. One of the most important was the goal to train human resources involved within all the AAP countries. The organization of an appropriate training program was actually a key point to guarantee success of the whole project and, as detailed below, one of the success of the project. The other goal was to provide AAP countries support in procuring, developing installing different aspects of the e-infrastructure depending on needs and request coming from different AAP countries and partners. In this context efforts were also done to development and/or making accessible custom tools for decision support tools for adaptation planning, strictly integrated within data. An example is actually the Climate Change Information Centre (CCIC) recently established in Mauritius.

The ultimate goal was also to provide an opportunity for Africa countries to be and use a cutting-edge approach to address the problem of climate data information.

3. Methodology

In this section we discuss the initial design of the e-infrastructure we aimed at build in the course of the project. This was planned at the beginning of our activities in the first few months of the 2011, following guidelines based on our previous experiences in working with African countries (see for instance reference [1]).

As a general rule we decided to follow a "do not re-invent the wheel" approach with the aim to borrow ideas from other projects, which have successfully implemented similar infrastructures in developing countries and adapt, if possible, their technical solution to fit the local context. An important aspect was also to team up with organization/institutions that have similar common requirements in order to share efforts and ideas.

We elaborated a few key concepts in the design of the e-infrastructure for climate data:

1. The e-infrastructure should be distributed and easily available to all AAP users, no matter which AAP country they belong.
2. The e-infrastructure would house the datasets, but would also have the capability of providing computationally intensive services for data analysis, visualization and for data generation by means of regional climate simulations as well.
3. The data analysis and visualization components would be provided through a data portal complemented with a collection of open source software tools.

3.1 Data Infrastructure Design

The proposed e-infrastructure was based on the concept of multi-tier infrastructure composed by three different tiers, as described in the following and reported in figure 1.

Tier0, the circle in the center is the main node of the e-infrastructure: it provides a large storage and all the general data services. The site has no infrastructural problem and the investment in IT should be minimal; the IT infrastructure is large and stable enough to host considerable amount of data and to deliver the required computing capacity. In-bound and out-bound connectivity should also not be a problem. Tier0 was placed in Trieste, Italy: IT infrastructure being provided by ICTP and human resources and competences provided by CNR/IOM team. It has to be noted that a large community, the RegCM one, is active there and this community could actually drive the data management efforts and e-infrastructures. Experts and competences are there and can be easily shared among participant countries.

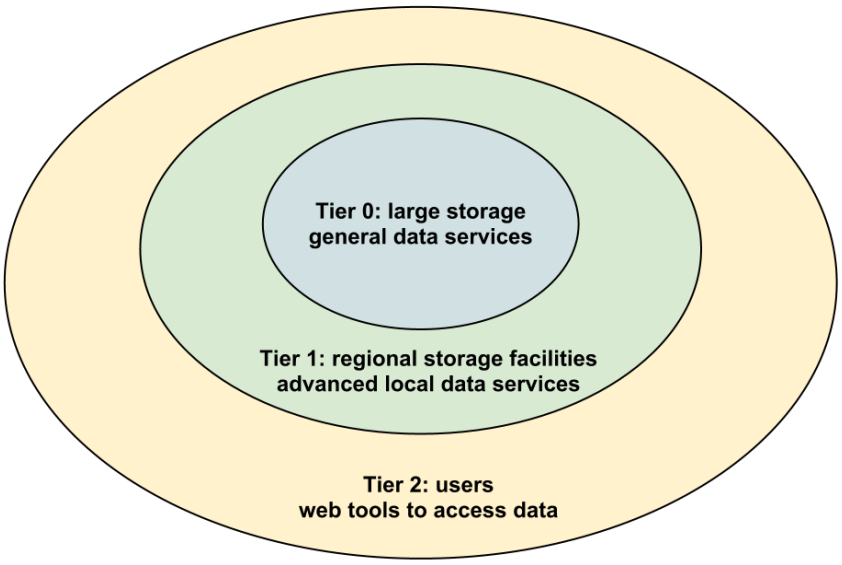

Figure 1: the Multitier Infrastructure

The outer tier **[Tier2]**, available to all AAP Countries, is actually a lightweight tier where people will access the e-infrastructure by means of some lightweight web user interface software. Eventually all the Tier2 countries should become a Tier1 center. However the initial design did not consider any infrastructural investment at the beginning of the deployment of the e-infrastructure.

3.2 Training Approach

The multi-tier infrastructure was designed to be incrementally built as soon as requirements and needs from AAP countries are identified and IT skills acquired.

For this reason a training program for capacity building was designed and associated to the e-infrastructure with the goal to create conditions to successfully create and deploy in different countries the elements of e-infrastructure. A two phases implementation program was devised.

In the first phase, after having designed the e-infrastructure, a series of the so called "awareness workshops" were scheduled to be run in Trieste. The aim of such workshops was to present and discuss the e-infrastructure to put in place and the role of such infrastructure within the project. As an additional goal we planned to enhance capacity and make aware IT teams from member countries and other relevant national stakeholders of all the elements of it (in term of hardware and software stack) and train them specifically on the procedures to install and maintain a Tier1 site. This first training phase should also have allowed the project to identify the first set of AAP countries where to set-up Tier1 centre.

Once the "awareness" phase was completed the second phase of the training program consisted to run in country specific installation workshops for Tier1 elements of the infrastructure. The overall objective of the in country workshops was to enhance capacity of local countries team to undertake the setup of climate data server and associated software services. More specifically the purpose of this workshop was to acquaint and train IT Staff on build and configure an HPC data server for climate data. An intensive training on a data management tools and climate simulations and data analysis was also part of the training to be offered to local climate scientists and final users.

4. Technology Description

In this section we briefly review the hardware and software elements we choose to build the multi-tier e-infrastructure and the "ad-hoc" customization proposed to tackle with different challenges faced in the course of the project deployment.

4.1 Tier 0

Tier0 hardware provided by ICTP through access to the Storage facilities installed in house. The access to ICTP infrastructure is actually through the software stack described later and it is completely transparent to the final users. Tier0 point of access is therefore created through a simple virtual machine that, properly configured, is able to link to all the data stored on the Storage facilities at ICTP made available through a dedicated web service.

4.2 Tier 1 Hardware Elements and Associated Software

A data server complemented by an UPS composes the Tier1 hardware component. The server is able to serve 20 TB of storage and is equipped with 12 computational cores. Some Hardware redundancy and the UPS guarantee a high availability of the server. The UPS is connected to the server and, when a power outage is in effect, is able to keep the system up and running for as long as possible. Ad-hoc procedures are in place to automatically reduce power consumption when the server is on battery, and eventually shutdown it cleanly when UPS power is below a certain threshold.
The server has been installed with the CentOS 6.x Linux distribution and the entire needed software environment to perform intensive computing for scientific climate simulations (SSH access, parallel and math libraries, compilers and so on). As clearly depicted IPMI [2] (Intelligent Platform Management Interface) tool was installed to allow remote assistance in case of problems. Picture two depicts clearly the HW and SW configuration proposed.

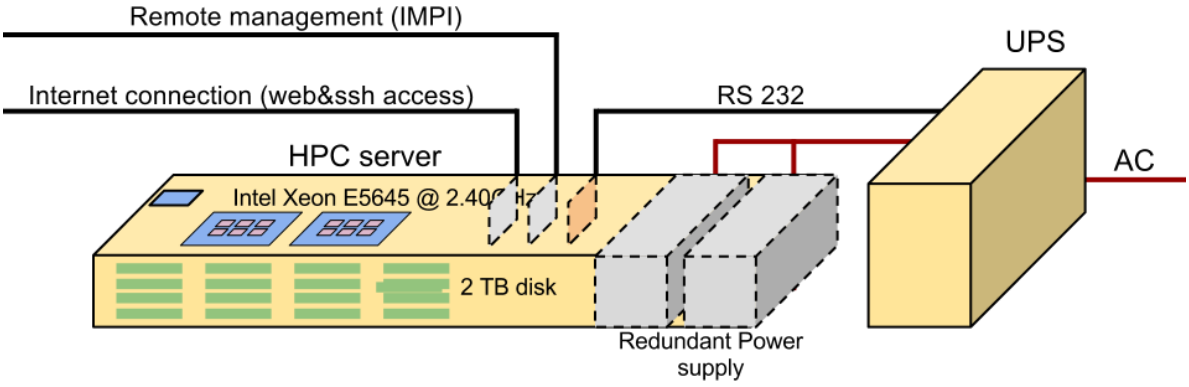

Figure 2: the Tier 1 HW Composition

4.3 Software Stack

The software elements of the e-infrastructure originally planned can be grouped in different layers to provide functionalities for:

- the management and maintenance of the Tier1 server itself (described above)
- the access and sharing of the scientific datasets stored in both Tier0 and Tier1 server;

- the execution of regional climate simulations and other models and the analysis of the results produced on Tier1 server.

We discuss in the following the two upper different layers in some details.

4.3.1 Access and Sharing of Scientific Datasets

This software layer is providing the core functionalities of both Tier1 and Tier 0 sites. Final users can access scientific data by means of a web browser, via the HTTP protocol with services provided by the RAMADDA [3], to browse and download data, and by THREDDS [4] service, to browse, subset and interactively visualize data..

We choose to use of the RAMADDA server as a general web based interface to users. RAMADDA is an open source data and content management system developed by UNIDATA that runs on inexpensive computing systems and provides access to heterogeneous, geo-spatial and multi-disciplinary data forms. Since RAMADDA is more than a data server, it is also used as a publishing platform for the generated materials that are made available and searchable by the decision makers. Users can scan through the enormous volumes of information and extract subsets for their region or project of interest.

Figure 3 shows the typical RAMADDA workflow, from uploading to publishing data, on Tier1 site e-infrastructure, after having defined the following different class of users:

- Scientific institution, scientific and government departments, (the stakeholders), able to upload and share content in a personal space;
- A data curator and data publisher, in charge of curate content uploaded by the stakeholders and to publish it;
- Public (anonymous) visitors.

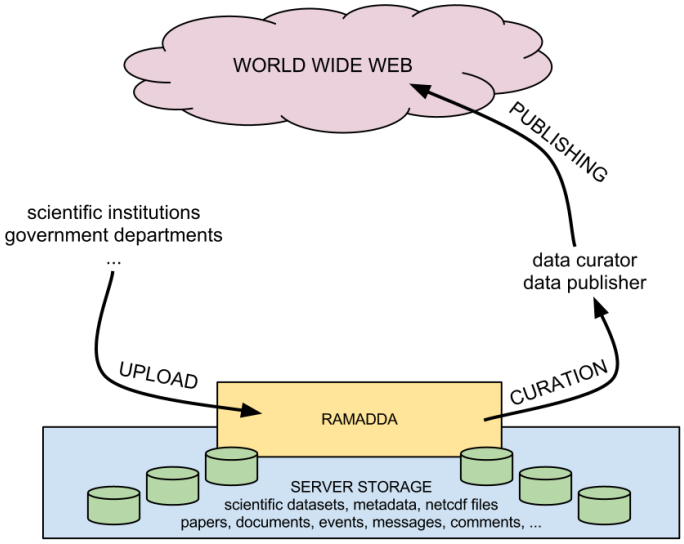

Figure 3: RAMADDA Server Workflow

In addition, Tier1 site hosts THREDDS (Thematic Real-time Environmental Distributed Data Service) catalogue, a service that allows users and third part applications to access data in a convenient fashion. Thanks to the OpenDAP protocol [5] support, the user is able to download not the entire file, but just a subset of it, limited to the domain of interest. This is of particular interest when the total size of the file is in the order of Gigabytes and when the bandwidth does not allow the download in a short time. Such a condition is often the normality in African countries, where infrastructure problems affect the Quality of Service of the network, and so the bandwidth of an Internet connection.

4.3.2 Scientific Software for Simulations and Analysis

The third layer of software integrated within Tier1 site is the scientific software to perform small/medium size climate simulation and the associated climate data analysis tools.

The modelling software proposed and installed on the server was the ICTP Regional Climate model RegCM4 [6], a simulation package developed at Earth Physics section at ICTP and distributed as open source software. The RegCM4 package is widely used and there is scientific network associated, Regcnet, which is well spread in Africa. WRF package [7] was also installed when explicitly requested by some AAP countries during the in country workshops. This was the case in Mozambique and Mauritius.

Many different analysis tools were made available to process climate data served on Tier1 site. Some of them are based on command line interface and are therefore available only for scientist using the Tier1 site for running/using climate simulation packages..

There was however the need to provide a powerful visualization and analysis tools able to access data through the web interface. This was identified in the Integrated Data Viewer (IDV) package [8]. IDV can easily access external server and it is portable on any platform so it represents actually the fundamental component for Tier2 sites allowing transparent remote access to climate data stored elsewhere. It can be used to create powerful graphics that assist with the understanding of climate processes and projections and can also be used as a communication tool for engaging stakeholders.

5. Results

The e-infrastructure design and the associated technologies presented in the previous sections were deployed over a period of two years. In this section we describe the implementation strategy and all the activities undertaken, outlining best practices, legacies and challenges and how they were effectively addressed.

5.1 Preliminary Activities (January – April 2011)

Official activities started at the beginning of 2011 when the e-infrastructure model and the action plan were designed and discussed within DIMC. A key AAP strategic partner for supporting countries with the development and use of the e-infrastructure was identified as the International Centre for Theoretical Physics (ICTP) based at Trieste. A memorandum of understanding (MOU) was signed in April between ICTP and UNDP/AAP project; ICTP commitment was twofold: Provide support on capacity building within the AAP countries as a training partner targeting both the stakeholders who will be setting up and administering the e-infrastructure and the scientists who will be using the e-infrastructure to their respective country goals. A team of people of the CNR/IOM center who collaborated in the past with ICTP provided human resources for the project while ICTP itself made available its IT resources to host the Tier 0 center of the e-infrastructure.

The architectural characteristics of the Hardware elements for Tier 1 center were also defined in early 2011 and the IRTSC/DIMC in collaboration with Trieste team scheduled the training activities of phase 1 of the capacity building program..

5.2 Awareness Training Phase (May 2011 - August 2011)

The established MoU aforementioned enabled the project to have two awareness workshops to be officially incorporated in the 2011 scientific calendar of ICTP. Both activities were organized according to the guidance of ICTP, providing logistic support to participants and using ICTP resources (formats and tools) for the activities.

The **Joint AAP-ICTP Activity on Special Training for UNDP African Adaptation Programme on building and using data servers for adaptation studies**" took place in

Trieste (16 - 28 May 2011) while "**Joint AAP/ICTP Activity on Special Training for install and use a Multi-Tier Data Infrastructure for storage and processing of climate related data for UNDP/AAP"** was held from July 25th to August 3rd.

The goal of the proposed workshops was to establish awareness among participants coming from AAP countries about the planned e-infrastructure and the role of such designed e-Infrastructure for climate modelling in adaptation studies.

A significant aspect of the two-week intensive program was dedicated to hands-on training on the software services described in the previous section. In both workshops there was an active participation by the RAMADDA and IDV developers, who presented in details the tools and methods as well as contributing to specific customization required by the project. The workshops also provided the opportunity to share knowledge and experiences/best practices among AAP countries.

During the last two days of both workshops, all participants were charged to use resources and knowledge acquired to develop a roadmap and demonstrate through country-specific mini projects, how they will implement the e-infrastructure in their respective countries. Each country presented their results during the final session of the workshops.

The participants of the first workshop consisted of 9 AAP Countries (Senegal, Namibia, Malawi, Ghana, Mauritius, Lesotho, Morocco, Cameroun, Kenya) with 15 participants; while 25 participants from 12 countries attended the second workshop (Mozambique, Tunisia, Congo, Ghana, Gabon, Lesotho, Morocco, Cameroon, Tanzania, Nigeria) attended the second event. Some participants of the second workshop (1 from ACMAD, 2 from Morocco, 1 from Lesotho, 1 from Cameroon), were also present in first one.

Participants were trained on Tier 1 server installation and configuration in both events. The hardware and software installations during the second workshop was performed on a similar hardware infrastructure that will later be deployed in their countries. The first HPC/Data server installation and management procedure manual was also released at the end the second workshop.

The second workshop also featured the setup of the basic elements of the Tier 0 site by means of an AAP RAMADDA server on a virtual machine hosted at ICTP: http://aap-repository.escience-lab.org/. This Tier 0 was setup and populated with preliminary data and linked by means of THREDDS catalogs to several ICTP climate data repositories.

At the end of the workshop participants made tools available for further work when they returned home. All participants went back with a virtual machine properly configured and with all tools correctly installed. This machine, easily deployable on local hardware, formed the initial core of future data server deployments and played a fundamental role in providing participants the right tools to show local user communities the range of potential applications. This increased the awareness and competences of the local/in-country IT teams of the non-destructive/fail-safe deployment of the virtual machine solution.

5.3 Tier1 Site Procurement and Implementation (July 2011 - February 2012)

The original plan to procure Tier1 systems was to have the order placed by selected countries in time to have the Tier1 package delivered to ICTP in Trieste during the second training event. This was intended to facilitate installation and management of the appropriate data and tools. After the training, selected AAP countries themselves were supposed to facilitate shipping of the server back to their home countries and setting up the infrastructure with support from the DIMC/ICTP team.

A major challenge to technical capacity is in the area of procurement. Much of the time the resource team focused on working with country teams to ensure technical specifications and related warrantees were in place. Even with this extensive support the procurement procedure encountered significant delays and was possible to proceed with orders only in

the last months of 2011. It has to be said that, differently from what we planned, countries decided acquisition independently and first round acquisition involved Congo and Lesotho and Burkina Faso that did not participate in the awareness-raising phase.

The equipment and related materials were delivered to Trieste between November and December and installation was planned for Q1 2012. This training event was a one-week hands-on training course solely organized for AAP countries that have procured the HPC data servers. The objective was to install and configure the complete system (which consist of HPC data server and the UPS) including system application software ready to be used in the respective countries. Teams from Burkina Faso, Congo, Lesotho and Mozambique (who were in the process of acquiring a Tier1 system soon) attended the workshop. After a successful workshop, the configured servers and accessories were delivered to the respective countries and the implementation of phase 2 of the training started.

5.4 In Country Training Events (March 2012 - December 2012)

In country training events was planned to start once Tier1 package was delivered the countries. The main goal of each workshop was to have the HPC data server fully configured with all its functionalities: storage area, remote management, web data server enabled in the dedicated place and/or institution chosen by of each AAP country.

The first round of training activities, performed in the first part of the 2012, was targeted to the first three countries that had acquired the system: Burkina Faso, Congo and Lesotho. Burkina Faso and Congo organized their training in March and April and resource persons were actually provided by DIMC/Dakar without involvement of the Trieste training team. The main goals of both workshops were met for both Burkina Faso and Congo but final hosting of the e-infrastructure is being finalized to ensure that the countries derive maximum benefits from the system and the right management team and institutional processes are properly established.

In June 2012 the workshop for Lesotho was organized with direct involvement of the Trieste team. The specific goals were achieved in that participants were able to connect and use it for their test applications and to determine the future usage of the server. The server was therefore the basis for establishing the initial core of future activities, providing participants with the right tools to demonstrate to local user communities the potential applicability of the tools and raise awareness and competence of the local IT teams. It has to be noted that network connectivity provided by the final institution (Lesotho Meteorological Service) was not enough to guarantee a full exploitation in term of remote usage of the server. As a result a high bandwidth wireless network was established to enable access from stakeholder institutions.

In Spring 2012 four more countries (Mauritius, Nigeria, Gabon Mozambique) ordered servers and associated accessories, which were delivered in June 2012 in Trieste, where the team performed a check and standard installation. Servers were then immediately delivered to the countries and a second round of in-country training events was implemented.

In July/August 2012 a very successful workshop was organized in Mauritius with resource people from: Trieste and. Server was properly configured and remote access was provided. Network connectivity was good, at least within Mauritius, making the server a great national resource. In addition to the e-infrastructure installation and training, the WRF and RegCM climate models were installed and workshop training sessions on their use and analysis of model results were also conducted. A similar successful workshop was organized in Mozambique in October during which participants were also trained in generating climate products for adaptation planning; also in this occasion all the goals were reached and server started delivering services in an appropriate location.. Unfortunately

there a poor Internet networks connectivity performance due a weak link between INAM (final location of the server) and Mozambique network operators.

Another workshop was organized in Gabon at the end of September 2012. There were some challenges with the installation due to a combination of factors (e.g. location, background of participants, and preparatory work prior to training). In effect, the location identified was not appropriate for such an exercise and to date no effort has been made to secure the recommended host institution with the right environment. The recommendations made include reinforcing the cooling system and appropriate Internet connectivity.

5.5 Climate Change Information Center Software Development (December 2012):

In the course of 2012 requests came to setup not only a computationally and data intensive system but also a so-called Climate Change Information Centre, to access and share knowledge products on climate change. The first request was made by Mauritius. The first Climate Change Information Centre was established during a dedicated workshop in Mauritius in December 2012: it will act as a data centre for climate change related data and information and assist in decision-making.

The Centre will also provide early warning and climate risk information to support climate resilient community-based initiatives. The service has been deployed adding to the standard AAP data server some additional services; a Drupal content management system, intended to be a container for of services and a user-friendly interface to enable the data curator publish content available to the public; and the Ushahidi platform[9,10], a crowdsourcing web platform for information collection, distribution and visualization on an interactive map. It allow users to submit information to it via multiple sources such as email, web form, SMS and micro blogging tools such as Twitter and was therefore integrated to provide a early warning and climate risk information.

The overall structure of the CCIC software site composition is described in figure 4.

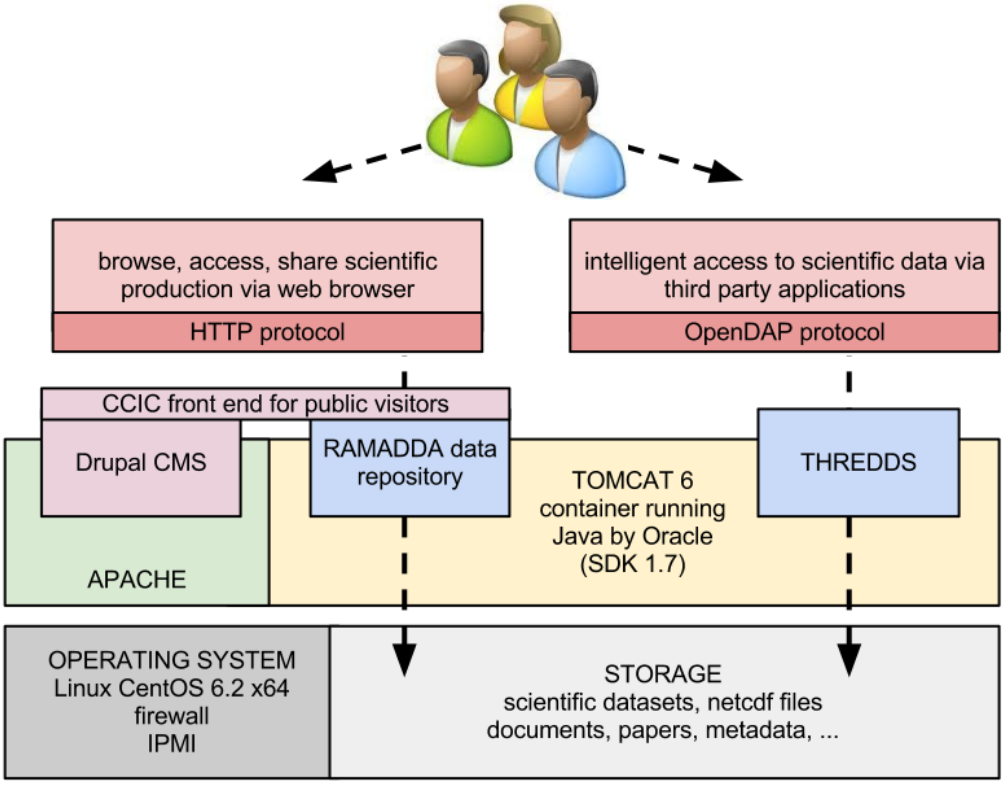

Figure 4: Overall Software Composition of Tier 1 Centre. The CCIC Service was firstly created in the second Mauritian Workshop, in December 2012.

6. Analysis and Discussion

In this section we discuss and analyse all the activities performed in the two-year period in order to assess the overall impact of the project. We try to measure the impact in terms of indicators of success and on the basis of the qualitative feedback we received through continuous interactions we had with countries.

The initiative has been very successful in all respect. It is the first time e-infrastructure has been widely applied to address climate change and development problems in Africa. The technical capability and infrastructure that is required for such a complex and intensive climate modelling and analysis exercise to provide robust data to inform decision and policy making was achieved. The specific achievements include the following below:

- 8 workshops were organized to setup the e-infrastructure and put in place the capacity to install, use and manage the infrastructure to support adaptation planning.
- Mauritius, Gabon, Nigeria, Burkina Faso, Congo, Lesotho acquired the infrastructures and teams trained to manage them with limited external support.
- Some countries were able to independently setup and manage the server with the available resources (Morocco and Niger).
- Almost all AAP countries were trained on the kind of e-infrastructure deployed and about the data management tools made available.

More importantly:

- Significant foundational partnerships on climate change at national, regional, continental and international levels are established through use of e-infrastructure.
- The e-infrastructure (HPC, data, decision support tools, network of institutions) established has enabled countries to prepare their national communications and related commitments under the UNFCCC.
- The critical mass of technical expertise/community-of-practice on e-infrastructure consisting of mentors and problem-solvers has been established Africa-wide

On a more in-depth analysis of the different phases of the project, we considered the awareness raising phase successful under many aspects: 16 countries participated (out of 20 belonging to AAP program) and about 40 people were trained. Moreover all participants show enthusiasm and actively participated in the events, producing several resources/materials as a starting point of future actions. A Google Grouplist was also setup at the end of both training for group discussions and support among the participants providing a sense of shared community and goals.

The e-infrastructure deployment was the key aspect of providing a comprehensive and integrated approach to data and information management.

The motivation behind the multi-tier e-infrastructure were based on the observation that climate modelling and associated data produced requires an IT effort and infrastructure far too complex and far too expensive for countries to do it on their own. This was confirmed later in the course of the project where we noted that apart from Morocco and Tunisia, most AAP countries, which acquired the Tier1 system, have not enough IT competences to manage such an infrastructure. We mention that in the original design Tier1 centres were originally thought to be hosted by AAP countries where a certain level of IT competences and capability are already in place and a clear need of the IT resource was identified.

We adopted a staged-approach building on a reliable and stable infrastructure, which could be used for a capacity building program. In the process when the IT competences are created and user needs appropriately identified, these resources can be complemented by other African resources and then scaled up to cover more countries. The actual evolution of the e-infrastructure was different from what we had initially envisaged as the lack of co-ordination among countries become a major challenge we had to address.

The overall coordination of different tier1 sites should also had to provide a sustainable approach on long term basis, being that all elements of e-infrastructure are linked together and thereby providing a single point of failure: again this long term objective is still to be reached due to the lack of communication and to the ending of the program itself.

The establishment of such multi-tier e-infrastructure provided a common platform for many countries to access and share common data, tools and methods. This means countries do not need sophisticated infrastructure and knowledge to access and use basic climate data. Countries with low capacities can now benefit from the knowledge and resources developed by the experienced countries such as Morocco. In this way AAP countries have access to the same core resources and capacities thus helping to build momentum for implementation across countries and Africa-wide.

There were some other difficulties as well; one of the weakest point was the fact that the people with the right backgrounds were not always selected for the workshop resulting in significant investment of time and resources with no value-for-money. There was also no clear plan on how their capacities and resources will be sustained beyond the workshop and project. This was further complicated by the fact that most participants who came from Francophone countries, lacked basic understanding of the English language to enable them understand the course contents and effectively apply the knowledge. To resolve the language barrier we placed bi-lingual participants among the Francophone participants.
Countries also lacked the capacity to develop technical specifications and manage the procurement of equipment so a joint team consisting of countries, DIMC/IRSTC Dakar and Trieste team was established to manage procurement. Due to extensive delays in country procurement processes, IRTSC undertook most procurement on behalf of the countries reducing the time from 12 months to under 2 months and hence unblocking a major barrier to project implementation.

However, despite these difficulties, in country training activities were successful in terms of number of events, number of people trained and infrastructure established and long-term goals of the overall project. The following table indicate quantitatively the success of this second training phase.

Table 1: List of In-Country Training Events

Date	**Place**	**Final location**	**Participants**	**Training team**
March	Burkina Faso	DCIME	20	DIMC
April	Congo	UNDP	20	DIMC
June	Lesotho	Lesotho Met Service	8	DIMC/Trieste
July/August	Mauritius	University of Mauritius	42	Trieste
September	Gabon	Direction General de la Meteorology	10	DIMC/Trieste
October	Mozambique	INAM	15	Trieste
December	Mauritius	GOC (Government Online Center)	24	DIMC/Trieste

All the countries where training events were organized were able to exploit the resources at least locally. Mauritius, Lesotho, Mozambique and Morocco were able to make the data services available on the Internet with an official IP and name registered. Congo and Burkina Faso were able to give remote access to users but, due to logistic constraints, they still are not able to officially make available the data services.

As indicated previously, there some challenges to implementation of the e-infrastructure, with most of them resolved or structures put in place to manage them. Specifically, the results were very much dependent on the level of the awareness in the countries.: disappointing results were obtained in countries where preparatory work was poor and overall, things were not properly managed locally.

Countries with poor network infrastructure had challenges in providing an acceptable quality of service within and outside the country. This was the case for instance in Mozambique and Lesotho, where the bottleneck was the link between the hosting institutions and the country networks.

The selection of participants was also not properly done in some countries where they either lack the people with the right background or sent people who had no interest of using the infrastructure. This was a generally consistent issue across all the country projects.- the target audience have not always been well defined from the start of the project and in most instances was due to lack of effective communication between the country focal point and the stakeholder institutions.

With regard to climate data analysis and simulation all countries reported significant progress in establishing resources and software tools (like RegCM and WRF). However, there is still some work to be done to bridge the gap between having computational resources available and researchers ready to use them to generate customer-driven climate products and services to support climate change and development in their respective countries. This point to a need for an extended capacity development program, which will require a significant effort in time and resources.

The overall program ended in 2012 and requires now an in-depth analysis to better quantify the long-term impacts and lay the framework for future activities. There is the need to document the knowledge products and resources as well as put in place sustainability measures to ensure the legacies of the initiative is sustained through on-going and future programming. There are already several attempts to construct and interact with on-going projects with similar goals. Some other projects were just discovered too late, see for instance the CLUVA [9] project presented in the IST-Africa 2012 conference [10].

7. Conclusions

We have outlined UNDP/AAP project activities undertaken over a period of two years with the goal of setting up a distributed multi-tier e-infrastructure, capable of providing AAP countries the data and tools for informed decision and evidence-based policy making. This is the first time such a system has been widely applied across Africa where cutting edge technology and innovative approaches have been extensively used to produce, apply and manage data and information for decision and policy making at all levels.

This is also the first time that a social network has been established around climate modelling infrastructure, data and information through the multi-disciplinary in country and regional community of practice formed during the initiative. This is evidenced in the number of invitations we have received to present our work in conferences and framing the WMO Global Framework for Climate Services, the United Nations Framework Convention for Climate Change and other related international initiatives. Another measure of the success of the initiative is the fact that countries covered the entire expenses of the activities enabling the IRTSC to save funds for other activities. In this respect the initiative has been transformational in bridging the digital divide in climate science that was clearly evident prior to the commencement of the initiative.

The set targets were exceeded and the interest generated within the international climate change community has been significant. The community of practice established through the training of about 150 people across Africa provides a critical mass of expertise that can generate, use and manage robust climate data and information to support dynamic multi-sectorial adaptation planning and decision-making. Foundational partnerships have been established at the national, regional, continental and global levels and as a net result they are now providing mechanisms and resources to sustain the systems and capacities established.

There is however more work to be done to sustain the legacies of the project. The major challenge is to keep the momentum at the end of the project and stimulate people to work by themselves. The established network will continue to support countries although the project is coming to completion at the end of 2012. Effort to continue supporting countries to build the established systems into existing and future programmes is on-going. The ClimDev Africa [13] and CORDEX[14] initiatives are examples of ways we are ensuring sustainability of the legacies. More important, continuously and actively engaging the AAP countries to better define their requirements and develop the appropriate solutions to their specific needs is being explored through on-going and future programming

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