Economic Commission for Africa

ACPC
African Climate Policy Centre

United Nations Economic Commission for Africa
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Working Paper 3

Assessment of Africa's Climatic Records and Recording Networks Including Strategic for Rescuing of Climatic Data

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AN ASSESSMENT OF AFRICA'S CLIMATE OBSERVING NETWORKS AND DATA INCLUDING STRATEGIES FOR RESCUING OF CLIMATIC DATA

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

ACMAD	African Centre of Meteorological Applications for Development
ACPC	African Climate Policy Center
AfDB	African Development Bank.
AGRHYMET	Agro-meteorology and Hydrology Regional Centre
AMESD	African Monitoring of Environment for Sustainable Development
AUADARE	African Upper Air Data Rescue
AUC	African Union Commission
CDMSs	Climate Data Management Systems
ClimDev-Africa	Climate for Development in Africa
COP	Conference of the Parties
DARE	DAta REscue
G8	Group of 8
GCM	Global Circulation Model
GCOS	Global Climate Observation Systems
GFCS	Global Framework for Climate Services
GOOS	Global Ocean Observing Systems
GSN	GCOS Surface Network
GSN	GCOS Surface Network
GTOS	Global Terrestrial Observing System
GTS	Global Telecommunication System
GUAN	GCOS Upper Air Network
ICPAC	IGAD Climate Prediction and Applications Centre
IEDRO	International Environmental Data Rescue Organization
IPCC	Intergovernmental Panel on Climate Change
IRI	International Research Institute for Climate and Society
MDGs	Millennium Development Goals
MODIS	Moderate Resolution Imaging Spectroradiometer
NAPAs	National Adaptation Programme of Actions
NMA	National Meteorology Agency
NMHSs	National Meteorological and Hydrological Services
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PRSPs	Poverty Reduction Strategy Papers
QC	Quality Control
QMS	Quality Management Systems
RAPs	Regional Action Plans

RBCN	Regional Base Climatological Network
RBSN	Regional Base Synoptic Network
RCCs	Regional Climate Centres (RCCs)
SADC-CSC	Southern African Development Community-Climate Services Centre
UNECA	United Nations Economic Commission for Africa
UNFCCC	UN Framework Convention on Climate Change
WIS	WMO Information System
WMO	World Meteorological Organization
WWW	World Weather Watch

ABSTRACT: Effective management of climate variability and change requires that climate information be used effectively in planning and that climate risk be incorporated routinely into development decisions. In order for this to happen in Africa, the National Meteorological and Hydrological Services (NMHSs) and other climate services providers in the continent must work to strengthen the observational networks, quality control, manage and exchange data as well as enhancement of their capacity to produce and deliver the full range of climate services in support of sustainable development. African Climate Policy Center (ACPC) as a continental body mandated to address the need for greatly improved climate information for Africa and strengthening the use of such information for decision making, by improving analytical capacity, knowledge management and dissemination activities. It works with various players in order to ensure that countries realize the need to address climate issues in their policy planning thus contributing to the national sustainable development. This paper has looked on the situation of climate data and observations network in the continent. It is shown that the spatial distribution is poor with least coverage over rural areas, many stations do not operate and data from some of the operating stations is not fed into the international system. The quality of data is still poor with gaps of missing data and in some cases there are inefficient quality control systems. There have been some efforts to reduce these problems through data rescue and filling gaps using remotely observed data from satellites and other sources. Furthermore, the paper looks at some possible coordination mechanisms that could be adopted in the continent to ensure that Africa's observations network, data quality management systems and archival systems make available enough of the required climate data, from many parts, and share it widely with other stakeholders. The NMHSs' observation networks need to be strengthened to provide local climate information which is required for various applications. African NMHSs and regional climate centres need to be strengthened to ensure that data archives at all levels are well maintained. ACPC has a role to foster collaboration among all stakeholders to ensure that all this happens so that countries are able to address well climate related issues at policy levels. The following are among of the key recommendations to make this happen:

- In order to reverse the deteriorating climate observation stations networks there is need for the reinvigoration of the African network through both sustainable maintenance as well as installations of new, preferably automatic, station. There is a need to improve data management and archive systems;
- Devise new approaches in filling data gaps by combining observations from all available meteorological stations and global products such as satellite proxies and climate model reanalysis data;
- Make inventory of data that has been rescued and that need to be rescued**.** Furthermore make data rescuing an ongoing continuous process**;**
- The principles of a framework like the WMO Global Framework for Climate Services (GFCS) would be well placed to coordinate climate data management and observations network across Africa. Furthermore strengthening Regional Climate Centres will improvement management regional data banks; and
- ACPC should coordinate with regional, sub-regional and countries and carryout advocacy, at the highest level, for investing in sustainable long-term climate observation networks and data infrastructure. It should also help in defining requirements for climate data for different applications and facilitate a means of implementing some of the identified gaps such as those by Global Climate Observation Systems (GCOS).

KEYWORDS climate data network, data rescuing, missing data, data sharing

1. INTRODUCTION

Climate and weather recording in Africa started during the colonial time with a few number of meteorological stations in the continent (Griffiths and Peterson, 1997). Due to the importance of weather and climate information for various socio-economic sectors, the number of meteorological stations increased with time. However, the quality of data i.e., the continuity and the distribution of meteorological stations in Africa are not dense enough for applications such as weather and climate forecasting, climate studies and climate projections.

Africa is a continent that has always been referred for having poor and inefficient meteorological observation network thus making it difficult to address important issues such as poverty reduction and national development which are being held back by the variability and other extremes of climate GCOS/UCECA/AU (2006). The problem of lack of climate data in the African continent has been addressed at many national, sub-regional, continental and global meetings including the World Meteorological Organization (WMO) Regional Association 1 (Africa) Sessions that are held after every four years, its relevant working groups and expert meetings, Global Climate Observing System (GCOS) and other discourses. Therefore, this paper is not discussing data problems in Africa as a new issue but something which has already been discussed in many previous venues. The paper therefore highlights climate data issues which the African Climate Policy Centre (ACPC) through its work programme can address to ensure that it meets its delegated mandate.

Effective management of climate variability and change requires that climate information be used effectively in planning and that climate risk be incorporated routinely into development decisions. In order for this to happen in Africa, the National Meteorological and Hydrological Services (NMHSs) and other climate service providers in the continent must greatly strengthen their observational networks and greatly enhance their capacity to deliver the full range of climate services in support of sustainable development. User sectors of climate information such as agriculture, health, energy, water resources management, natural disaster prevention and others need to identify their needs and work closely with the service providers to ensure that, together, providers and users of climate information can substantially improve development decision making.

The global and regional framework for mainstreaming climate into development in Africa is already largely in place. Following widespread recognition, in 1997, that climate observing networks were deteriorating in many parts of the world, the Conference of the Parties (COP) to the UN Framework Convention on Climate Change (UNFCCC) encouraged the international sponsors and Secretariat of the Global Climate Observing System GCOS to organise a programme of regional workshops to identify priority climate observing needs in developing regions. This programme led to the development of Regional Action Plans (RAPs) in ten distinct regions to address these priority needs. In Africa, separate workshops were organised for the countries of eastern and southern Africa (in 2001) and western and central Africa (in 2003), which developed RAPs containing some twenty-four projects whose effective implementation would largely contribute to strengthening the observation network to meet the priority needs identified at that time (Tan et al., 2004).

Other efforts that have tried to address Africa's climate data issues include, among many others, the Africa Regional Strategy for Disaster Risk Reduction published in July 2004 by the African Union/NEPAD, United Nations Economic Commission for Africa (UNECA), and the African Development Bank, with response to floods and droughts as major concerns. In 2005, the G8 countries recognized that an urgent action was required to help African countries adapt to climate change. Improving access and capacity to use climate information in planning was noted as a key concern. In the Gleneagles Plan of Action, the G8 countries committed themselves to support efforts to establish or upgrade observing systems to fill data gaps, expand capacity for analysing and interpreting data, develop decision-support systems and tools for local needs, and strengthen existing African climate institutions. Sectoral users of climate information and the international development assistance community emphasized that if Africa was to benefit from improved climate information, more than just improving observing systems was required. An integrated strategy was needed, encompassing observations, climate services, climate risk management, and policy development.

Several Workshops have been organized by WMO and other partners to develop an end to end approach for dealing with climate databases that have gaps and those that are still in various forms that are not easily accessible. This has included organizing training workshops on data rescue and digitization supported by software and provision of computers to countries as well as training seminars on using climate data for the analysis of climate extremes which occurred in the past. Furthermore WMO with partners have develop climate data management systems such as CLISOFT and CLIDATA which have proved to be very useful in climate data management including Quality Control (QC) and archiving in a number of developing countries including some African countries.

This paper looks at the coverage and distribution of climate data networks, mechanisms of rescuing the existing data and sharing/access, and look at innovative ways of enhancing the climate change understanding such as technologies, infrastructure and capacity building aspects.

2. SITUATION ANALYSIS OF AFRICAN CLIMATE DATA OBSERVATION NETWORK AND DATA

2.1 African Climate Data Observation Network

The density and coverage of existing African climate data observations network have generally been described in many literatures as poor and sparse (Parker et al., 2011; Institute Water for Africa; Washington et al., 2006). These studies warn that there is need to use with care and caution gridded and assimilated climate data derived from Africa. Institute of Water for Africa tried to show the scarcity of the coverage by comparing with climate observations network of Germany (http://www.water-for-africa.org/en/station-density.html, accessed on 5th Aug., 2011). In Africa, there are about 1,152 weather stations reporting to WMO and one weather station covers an area of 27,347 km², while in Germany there are 287 operating WMO weather stations and the area covered by one WMO weather station is 1,244 km². Hydrological stations in Africa (without the area of Sahara) also have low density. There are 888 gauging stations in an area of 21,300,000 km², while there are 1150 gauges per 357, 114 km² area of Germany. This comparison provides the picture of the status of weather and climate data network in Africa in comparison to other parts of the globe. In some cases even the present observing stations do not either make observations or sometimes the information collected is not transmitted into the international network.

According to the Secretary General of the World Meteorological Organization, Michel Jarraud (Nov.6, 2006), Africa's weather and climate monitoring system is deteriorating and needs major improvements to meet the challenges of climate change. "Overall it is estimated that Africa needs 200 additional automatic weather stations, a major effort to rescue historical data and improved training and capacity building on climate and weather reporting," he said. Jarraud made his comments at a press conference held ahead of the UN Climate Change Conference that opened in Nairobi, Kenya in 6 November, 2006. At the same conference it was pointed out that despite covering a fifth of the world's total land area, Africa has the worst climate observation network of all continents, and one that is in a deteriorating state. Some of these aspects have also been expressed in different meetings (for example such as those of IPCC, UNFCCC and GCOS) where climate data related issues in Africa have been discussed.

The network of WMO World Weather Watch (WWW) stations provides real time weather data which are a vital input to weather and climate forecasts worldwide as well as forming the basis of international climate archives. There are 1152 WWW stations in Africa giving a station density of one per 26,000 km^2, 8 times lower than the WMO minimum recommended level (Elasha et al., 2006). This shortage of data is exacerbated by an uneven distribution, leaving vast areas of central Africa unmonitored, and the lowest reporting rate of any region in the world.

According to the list of the regional station networks of WMO (www.wmo.int, June 27, 2011), the reporting network as Regional Base Climatological Network (RBCN) and Regional Base Synoptic Network (RBSN) for Africa is comparable sometimes better covered than other continents (Table 1 and 2). However, the special coverage of the network varies widely from country to country. For example, the number of stations contributing from Kenya is about 18 while from Ethiopia which is larger in size is only 16. Over 90 stations from South Africa contribute to the Network. This disparity and unevenness in national network coverage introduce bias to the data especially when using in studies, research and development activities. In such a situation then one does not expect global climate products to address national scale issues properly. The basis of the sources of the poor nature of African climate network is based on both the regional networks and national networks that report to the outside world through WMO.

[1]**Table 1**: List of Stations Comparing the Regional Base Climate Network (RBCN) in all WMO regions (Source: WMO web page)

No.	Continent/Region	RBCN Reporting Stations	CLIMAT	GSN	Temp	GUAN
1	Africa	743	737	158	24	24
2	Asia	675	666	263	23	23
3	South America	314	309	105	18	18
4	North America	325	317	176	23	23
5	South West Pacific	257	251	151	39	39
6	Europe	596	585	139	24	24

Table 2: List of Stations Comparing the Regional Base Synoptic Network (RBCN) in all WMO regions (Source: WMO web page)

No.	Continent/Region	RBSN Reporting Stations	Surface	Radiosonds	Radiowinds
1	Africa	793	784	84	78
2	Asia	1415	1366	275	30
3	South America	443	436	53	1
4	North America	623	561	133	0
5	South West Pacific	412	400	92	14
6	Europe	908	840	127	0

Moreover, it is indicated in the GCOS Surface Network (GSN) report covering the period of Nov. 2010 – April 2011 (Fig. 1) that most of stations which are not recording or are recording less 50 % of the time are located in Africa. This is a clear signal that, in Africa, in addition to less number of stations which is usually inadequate network, the data recording and transmission is another pressing challenge.

Another challenge in African is the inaccessibility of the data from the national networks. Washington et al., (2003) in their African Climate report described that many counties in Africa have useful networks of secondary stations which do not report internationally. The issue of data availability to the international community is a sensitive one and needs to be approached with the needs of the African climate community in mind.

[1] *CLIMAT = Climate; GSN = GCOS Surface Network; Temp = Temperature; GUAN = GCOS Upper Air Network*

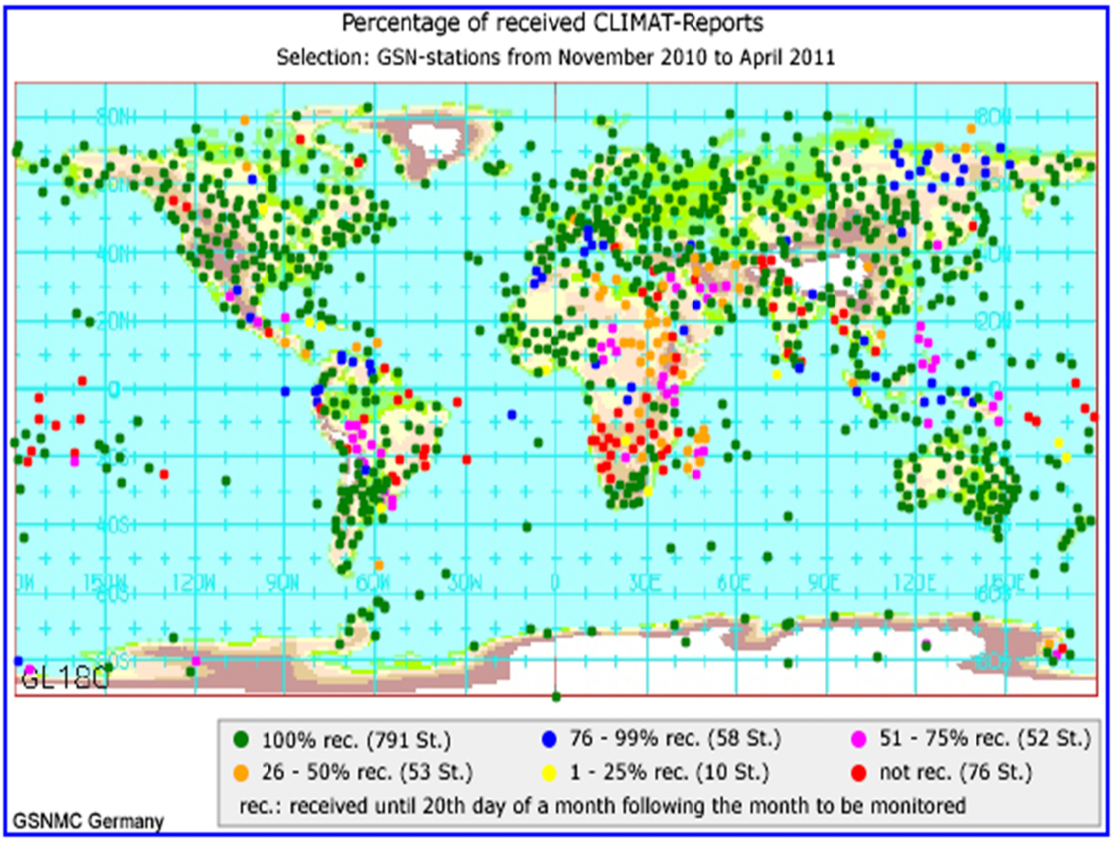

Figure 1: Surface Network (GSN) stations reported from Nov. 2010 to April 2011

Thirdly, the climate observation network in Africa appears to be spatially uneven. Most of the stations are found in cities or airports which in most cases are confined along the main roads. Often times, researchers complain about the closure of stations and scanty observations like central part of Africa. The central part of Africa plays a role as moisture sources but little is known about it.

A country like Ethiopia which has about 60% of the continents mountain chains that have dominant influence in modulating climate phenomenon in the region due to its topographic feature. However, its stations reporting to WMO are comparatively smaller in number when compared to those countries that are smaller in size and with less topographic effects. Similar comparison and analysis can be made to other countries. It is only South African that contributes data to WMO from more than 90 stations.

In 2009, in recognition of the challenges of data in Africa, WMO announced a plan to install about 5000 additional automatic weather stations across Africa under the climate change initiative Africa (UN News Centre, 18 June, 2009). This obviously would enhance weather forecasting (short and medium range) for immediate use. As the performance of this activity is yet to be seen, most immediate activity in Africa from climate change perspective is i) rescuing exiting historical data from the archives/stores and enhance climate data series, ii) Establish a protocol to incorporate more stations as part of global reporting network for climate modeling. This undoubtedly enhances the baseline scenario and the Global Climate Models (GCM) outputs. It is known from our countries and through discussions with several people from NMHSs in Africa, less than 10% of the data is reported to WMO and other international communication channels.

According to IRI (2006), African NMHSs should be service providers so that they can have much potential to offer to decision-makers and the development agenda, besides their current contribution to public security through weather forecasting. For instance, they could:

- Provide an enhanced range of useful climate risk management services;
- Assist with delivery of the Millennium Development Goals (MDGs) and adaptation to climate change;
- Contribute useful services for integrated water resource management;
- Assist with hazard early warning and disaster risk reduction; and
- Contribute productively to real-time environment monitoring.

2.2 Availability and Need for Quality Controlled Climate Data

In many African countries, weather and climate data are available at NMHSs. Some data are available at relevant regional institutions such as the IGAD Climate Prediction and Applications Centre (ICPAC), African Centre of Meteorological Applications for Development (ACMAD), Southern African Development Community-Climate Services Centre (SADC-CSC), AGRHYMET Regional Centre and others. These data are archived either in a paper form or soft copies depending on the institutional capacity and ability. WMO with some partners have made an effort to develop Climate Data Management Systems (CDMSs) such as CLISOFT and CLIDATA which some countries are using to archive data into soft copies in their databases. These are replacing the CLICOM software that has been used in many countries for many years. Therefore, countries with the necessary facilities have by now most of their data in soft copies which makes it easy to access and use. Most countries do not provide their data freely to users, something in some countries has caused misunderstandings between the providers and users of such information. Some effort has been made in a number of countries in the areas of data rescue thus improving their data bases.

Modernizing data management system minimizes the risk of losing climate data. Most of the African countries are using different software for the climate data management system. From figure 2, for example, Ethiopia and West Africa are using the CLIDATA, most of the southern African countries are using CLIMSOFT, and three countries are using CLISYS for climate data management. There are also African countries which have no climate data management system within the standards of WMO. Even if the countries are introducing modern technology for their climate data management, maintaining and upgrading the data base system is a challenge. This is mainly due to the lack of trained manpower and resources. Those professionals who trained in data base management system are leaving the African NMHSs for better payment and working environment.

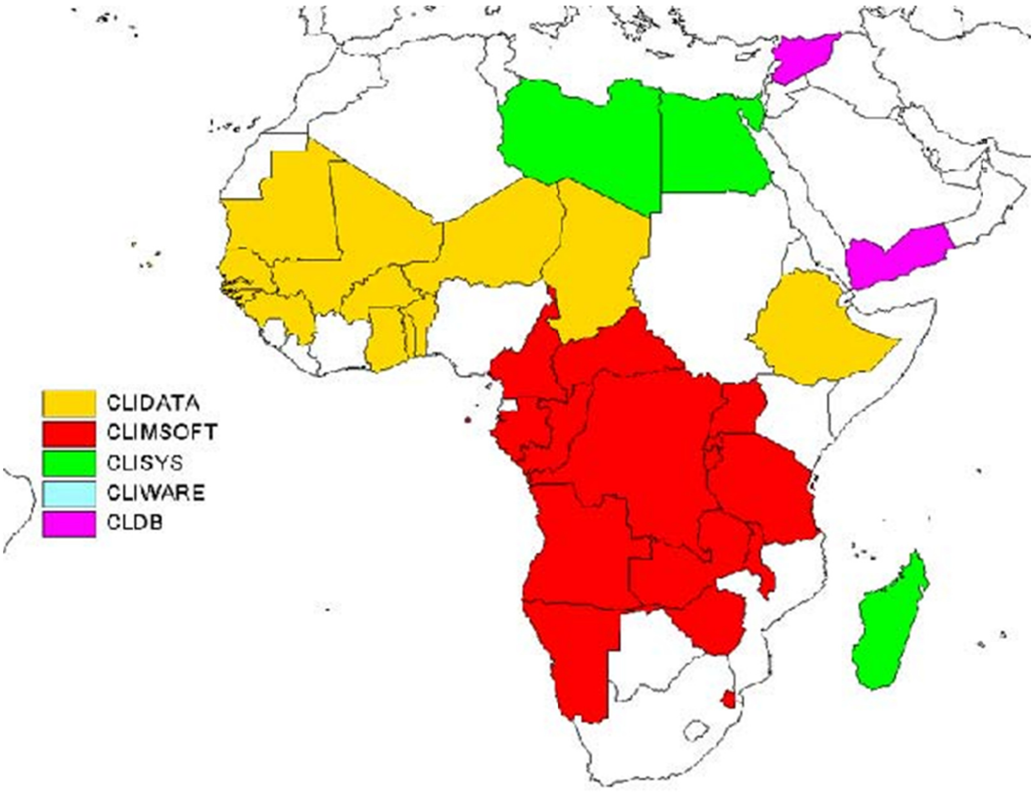

Figure 2: Data base software used by African countries (source www.wmo.int accessed in May 2010)

Climate data and their associated metadata are fundamental for the development of climate products, applications, and services and research. The requirements of climate practitioners and researchers to analyze and detect climate change and variability and develop seasonal-to-interannual prediction systems have increased the importance of climate data (Page et al., 2004). Climate data is also important for verification of seasonal-to-interannual forecasts, hindcasts and to generate future climate scenarios.

Digitizing the observed historical climate data and metadata will maximize the availability and the quality of climate dataset which is important for long term climate monitoring, specifically for analyzing the trend in the occurrence of the extreme events that require high temporal and spatial resolutions.

Weather forecasting (24-hour to a few days) is the mainstay of the NMHSs in sub -Saharan Africa, and is important to a range of stakeholders such as air and marine transport, commercial agriculture and the general the public in areas that are prone to extreme weather conditions such as cyclones. Information such as historic climate variability, real-time monitoring and seasonal forecasting, has more value than weather forecasting for management of infectious diseases and food crises, and more generally for economic and social development planning in Africa especially in rural areas. Furthermore, climate information is required for operational and research needs to refine predictive models for Africa. Therefore, consideration should be given in strengthening such kind of needs and emphasizing on new needs such as those of (a) hydrology, (b) early warning, (c) environmental monitoring and (d) future trends. For such purposes, it is important to acquire quality controlled and sufficiently checked data.

Well quality controlling procedures need to be observed in all weather and climate data archiving processes for data that are needed in areas of applications.

2.2.1 Complete Archives of Daily Observations

Complete, quality-controlled archives of historic daily observations are central to many development applications. They provide the basis for understanding trends, deriving climate statistics of interest, and placing current observations into historical context. Agricultural planning and engineering (e.g., solar energy, bridge, dam, coastal protection) design rely on climatological information derived from historic observations. Climatic time series developed from well quality controlled data are particularly important for water resource management. Levees, dams, and reservoirs are often engineered on the basis of inadequately short records of flood levels, with dramatic examples of inadequate flood or drought protection.

Historic data are the basis for downscaling and calibrating forecast products, and calibration of satellite data. Food aid and insurance applications use historic observations with statistical or simulation models to quantify agricultural production risk. Historic observations are essential for evidence creation when used in detailed analysis of climate and specific societal outcomes, and are key to the creation of products based on an understanding of such relationships such as weather insurance.

2.2.2 Near-Real-Time Observations for Operational Management and Early Warning System (EWS)

Near-real-time climate observations serve as a useful proxy for climate-sensitive variables, such as soil moisture and habitat for disease vectors, which can be more difficult to measure. Crop and forage production, disease vector populations, and risk of flooding and landslides are all sensitive to the recent history of rainfall. Operational systems for forecasting these impacts for management or early warnings derive, at least, some of their predictability from near-real-time observations. Since information may be required before network data can be collated and disseminated, satellite data are now widely used for large-scale weather monitoring in near real time. Most of the semi-operational rainfall estimates use rain gauge data to calibrate the satellite estimates. Because only a portion of the synoptic observations is available for these adjustments for most of Africa, the quality is much less than it would have been if they were adjusted using all locally available gauges. While satellite data provide good approximations of rainfall in many areas, interference from humidity, temperature and dust degrade their quality. Rigorous quality check and blending satellite data with the available rain gauge data would help to overcome these problems. Putting both the gauge data and the gauge-adjusted estimates on a rectangular grid simplifies to use with other data of interest to multiple users, including agriculture, food security, water resources and disease control planners, within a GIS. This approach could be implemented as part of the Climate Data Management projects envisioned in the RAPs of GCOS. One important technical gap often found is a lack of broader understanding as to how best to use the satellite data services to which Met Offices have a privileged access as part of the global weather community. This may be rectified to some extent by the impending European Commission programme, African Monitoring of Environment for Sustainable Development (AMESD), but still has much under-exploited potential.

2.2.3 Prediction for Operational Management and EWS

Where proven to have skill, forecast products at different time scales (short range, medium range, seasonal) may contribute to operational management (e.g., timing of water release from a dam) as well as hazard management (e.g., malaria early warning) and longer-term planning (e.g., agricultural planning for temperature sensitive crops) when integrated into an appropriate decision-making framework. Given the relatively long history of use, the direct use of daily weather forecasts is generally well established. The value of seasonal forecasts derives largely from the ability to forecast impacts such as disease risk, reservoir inflow or crop or forage production, often using models that incorporate historical and near-real-time observations and climate forecasts. These models need use of well quality controlled data.

2.2.4 Climate Change Scenarios for Infrastructure, Policy and Investment

Managing climate variability today is an essential but not a sufficient step toward adapting to climate change tomorrow. GCM based climate change projections are generally consistent in predicting temperature rise across Africa, but show considerable uncertainty about both the magnitude and direction of changes in precipitation. Appropriate use of a range of such projections combined with analysis of trends in quality controlled historic data can contribute to the understanding of future trends and uncertainties that are crucial for the long planning horizons involved in infrastructure planning and many policy and investment choices. It is important that countries take a strategic view on likely climate change impacts and start to adapt accordingly. Much greater priority is required for development of National Adaptation Programmed of Actions (NAPAs) and their integration in Poverty Reduction Strategy Papers (PRSPs). For infrastructure, the particular challenge posed by climate change is to incorporate likely future trends into designs so that they build resilience for future conditions as well as for present ones. It should be noted that no realistic scenarios are available in Africa that could be used to drive climate change application scenarios at local sector specific levels. This calls for more research and capacity building for the downscaling of climate change projections for local sector specific applications.

2.2.5 Spatial Information

For many development applications, a particularly useful way to integrate climate information with other information relevant to decisions is to use spatial software like GIS to explore relations and create maps. Maps (for example, Agro-ecological zone, disease risk) based on statistical or rule-based decision models and informed by climatology (and often a wide range of other non-climatic information) help to indicate which policies are appropriate, what investments should be made, and where research and intervention should be targeted. Similar maps and models can be used operationally as indicators of the current status of the season, or as indicators of changes in risk, when they incorporate near real-time weather and possibly climate forecast data. For example, crop models driven by near real-time daily weather and historic climate information are incorporated into food security models, and malaria early warning models are driven by seasonal changes in weather-related risk.

In recognizing the importance of systematic observation to further the needs of the UNFCCC Conference of the Parties (COP) noted that adequate high quality data for a variety of climate-related purposes is not available in many countries due to insufficient geographic coverage, the low quantity and quality of the data produced by current global and regional observing systems, and the failure to rescue available historical data. These problems are especially acute in Africa, where lack of funds for modern equipment and infrastructure, inadequate training of staff, the high costs of continuing operations, and problems associated with political instability and conflict are often major constraints (IRI, 2006). To begin to remedy this situation, the COP invited GCOS to organize a Regional Workshop Programme to identify priority climate-observing needs in ten developing regions. For each region in the programme, Regional Action Plans were developed to address these priority needs. Each Action Plan is a strategy document containing brief descriptions of projects identified as priorities by the region as a whole.

In the case of sub-Saharan Africa, two workshops were held and, subsequently, two RAPs were developed, one for eastern and southern Africa countries and the other for western and central Africa countries. These action plans contain considerable detail and can be referred from the GCOS website at http://www.wmo.int/pages/prog/gcos/index.php. The most important issues were that both plans contain projects that address needs for climate-related observations, needs to improve information availability, and needs to build climate application partnerships for decision-making. Common themes in the action plans are improving and sustaining operational observing networks, such as the GCOS Surface and Upper Air Networks (GSUAN); recovering historical data; improving national and regional coordination; education, training, and capacity building; and national planning and reporting.

2.2.6 World Meteorological Organization Strategy and Projects for Climate Data

The World Meteorological Organization through its various programmes and activities helps its members, in particular those from developing countries (including African countries), to improve their understanding and assessment of impacts, vulnerability and adaptation. The goal is to make informed decisions on practical adaptation actions and to take measures to respond to climate change on a sound, scientific, technical and socio-economic foundation, taking into account current and future climate change and variability. WMO at its Fifteenth Congress Session held in June 2010 in Geneva, Switzerland agreed to establish a new Global Framework for Climate Services (GFCS) with the goal to "enable climate adaptation and climate risk management through the incorporation of science-based climate information and prediction into policy and practice at all levels". This will be achieved through:

- Working with NMHSs to support climate-policy-related research at the local, national and regional scales and will provide WMO Members and NMHSs with practical information in developing new high-level decision-making and policy types of climate information;

- Developing regional working mechanisms on weather and climate extremes with services of NMHSs on weather and climate extremes gain in quality if they are based on a thorough understanding and appreciation of the uncertainties and constraints associated with the use of both observational data and climate change projections based on regional and global models. This is more easily accomplished on a regional basis than national; and

- Provision of guidelines to enhance NMHSs information delivery on climate change. The content of the guidelines developed by WMO through these activities and the results of the extremes analyses support climate-policy-related research at the local, national and regional scales and will provides WMO Members and NMHSs with practical information in developing new high-level decision-making and policy types of climate information. Local authorities and national decision-makers will be able to utilize the extremes analyses for their country or region as input for climate change assessments and the formulation of adaptation and mitigation strategies. It is information on the longer multi-decadal time scale that is needed for governments to minimize and adapt to the societal and environmental impacts of climate variability and change. For adaptation planning, the longer (multi-decadal) time scales are particularly relevant, because nearly all infrastructure design relies on assessment of probabilities of extremes with return periods of 20 years or more. Therefore, accurate climate data with longer records are very important.

Successful accomplishments on these aspects need quality climate data that are well managed.

3. EXISTING INSTITUTIONS AND COORDINATION MECHANISMS FOR CLIMATE SERVICE, MANAGING AND SHARING OF DATA

3.1 Climate Data and Services

At present climate data is little used in development processes in Africa because of weaknesses in both demand for, and supply of, pertinent climate services. However, climate variability and change are posing significant challenges to societies worldwide. Timely communication of climate information helps prevent the economic setbacks and humanitarian disasters that can result from climate extremes and long term climate change.

Climate information also plays a crucial role in national development planning, for managing development opportunities and risks and for mitigation and adaptation. Efficient application of climate services requires the integration of climate information into the policies of various sectors.

Climate services include, among others, the dissemination of climate information to the public or a specific user. They involve strong partnerships among providers, such as NMHSs, and stakeholders, including government agencies, private sectors, and academia, for the purpose of interpreting and applying climate information for decision making, sustainable development, and improving climate information products such as predictions and outlooks.

WMO members provide a number of climate services at the global, regional and national level to a large variety of users including individual decision and policy makers as well as organizations such as NMHSs, universities, and humanitarian organizations. These services are covered in more detail in the rest of the climate services section.

3.1.1 Poor Climate Data Due to Gaps

Climate observation networks which should generate the climate information needed for climate risk assessments and quantifying trends in climate are weak and deteriorating. Continuous record of climate data for 30 years is only found in few stations. Due to lack of investment and the brain drain, meeting of demand, the level of technical expertise able to support climate monitoring network, climate data processing, and the current level of activity are generally low. As a result of these problems, government institutions, developmental practitioners and service providers engaged in climate sensitive sectors of the economy are rarely oriented to plan or manage climate risks.

However, there are few international data centres which develop and maintain high quality, homogenized, global data sets, combining land and sea surface data while also having a complete set of data running from the present back to more than 160 years.

3.1.2 Maintenance of Data

Every climate database is arranged in a certain way to help facilitate the storage and retrieval of the information. The way the data is arranged depends on the format used. The format used is very important for the quality of the resulting system, and in particular for its maintainability. An inappropriate format will tend to make the system harder to maintain.

An important part of the quality management of NMHSs is the data Quality Control (QC) process. The QC process should be designed to check the quality of the whole data-flow process. It should ensure that data is checked and, to the extent possible, is error-free. There are several points where errors can creep into the data, and so these must be detected and eliminated, and if possible, the errors should be replaced by the correct values (while also retaining the original values). Errors can come into the data set at numerous times including: the condition of the station site; instrument/sensor; data transmission or data entry stages. Climate monitoring requires a long term commitment to quality and stability (Trenberth et al., 2002). Increasingly, NMHSs are taking a systems approach to ensuring that these requirements are met. These Quality Management Systems (QMS) are developed to address all aspects of monitoring programmes, from the planning phase, through equipment selection, procurement and installation, operations, inspection and maintenance to data reporting, processing and archiving (WMO, 1996).

3.1.3 Data Exchange

The exchange of data between NMHSs is essential for climate monitoring and various applications. This may include both the storage and use of data (and metadata) from other countries in the database of one NMHS, and the transmission of data to Global and Regional data centres. A list of Global and Regional data Centres can be found in http://www.wmo.int/pages/prog/wcp/wcdmp/csm/global_en.html.

Resolution 40 of WMO provides clear guidance on data sharing and exchange. WMO Member States have the obligation to share data and metadata with other members of WMO. Two types of data have been identified by the agreements: “essential” and “additional” data. A minimum set of “essential” data has to be made available with “free and unrestricted access”. However, members may include more information under the “additional” category than just the minimal set.

Members of WMO volunteer a subset of their stations to be part of various networks, including:

- The GCOS Upper Air Network (GUAN);
- The GCOS Surface Network (GSN);
- The Regional Basic Synoptic Network (RBSN); and
- The Regional Basic Climatological Network (RBCN).

Nomination of stations into these networks implies an obligation to share the data internationally using standard procedures and transmission protocols. Several data centres are linked to the WMO Global Telecommunication System (GTS) of the WMO Information System (WIS). Thereby they constitute international climate data archiving centres serving various users.

It is also important to note that data observations for the Global Ocean Observing Systems (GOOS) and Global Terrestrial Observing System (GTOS) contribute useful marine and terrestrial climate data respectively. Observational network of these systems need to be sustained and strengthened.

3.2 Principles of Climate Monitoring

Widely accepted principles for long-term sustainable climate monitoring have been identified and have been adopted by UNFCCC. These principles are as described below (Neil P et al., 2003; Karl et al., 1995; GCOS, 2003; WMO (1981a and b, 1996)):

(a) The impact of new systems or changes to existing systems should be assessed prior to implementation;

(b) A suitable period of overlap for new and old observing systems is required;

(c) The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e., metadata) should be documented and treated with the same care as the data themselves;

(d) The quality and homogeneity of data should be regularly assessed as a part of routine operations;

(e) Consideration of the needs for environmental and climate-monitoring products and assessments should be integrated into national, regional and global observing priorities;

(f) Operation of historically-uninterrupted stations and observing systems should be maintained;

(g) High priority for additional observations should be focused on data-poor regions, poorly-observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution;

(h) Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation; and

(i) The conversion of research observing systems to long-term operations in a carefully-planned manner should be promoted;

(j) Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.

3.3 Coordination Mechanism and Managing Climate Data

Coordination of climate data is implemented at different levels starting from the national to the international level. Coordination at national level for managing climate data and information in most countries in Africa is centrally done through the NMHS or any other designated institution. This institution is usually responsible for the storage and cataloging of all available climate data and also responsible for providing such information to whoever wants to use such data and information.

National coordination for the collection, archiving, processing and dissemination of climatological data should be done in accordance with WMO recommendations. In its guide to climatological practices, WMO recommends that climatological data should be considered as part of a national wealth, and the national meteorological agency in each country should normally be the authority which is officially responsible for all such information. The central agency so designated should also be responsible for the storage and cataloging of all climatological data.

Regional coordination for the collection, processing and archiving of climatological data should be done between national and regional centres. At sub-regional and regional level there are centres that have also responsibilities of storing some climatological data and information. For example, at the continental level ACMAD 's objectives and functions include the archiving of all African historical data, provision of uniform data format, and ensuring of efficient data and products exchange. ACMAD has been designated as a central depository for the African Climate data. On the other hand, at the sub-regional level ICPAC's functions include, developing and archiving national and regional climate data banks, networking with WMO, NMHSs (especially those from the sub-region) as well as regional and international centres for data and information exchange.

The planned WMO Regional Climate Centres (RCCs) when become operational will contribute to the available regional institutions that will have the responsibility of maintaining regional data bank for climate data. Among the responsibilities of the RCCs is to maintain a data bank and build capacity in data management for the region. It is therefore highly recommended that these centres be established as fast as possible.

At a global scale, the coordination roles of WMO on climate data and information are well elaborated in Article 2 (a, b) of the WMO Convention (WMO, 2003). These among others state the following:

- To facilitate worldwide cooperation in the establishment of networks of stations for the making of meteorological observations as well as hydrological and other geophysical observations related to meteorology, and to promote the establishment and maintenance of centres charged with the provision of meteorological and related services; and
- To promote the establishment and maintenance of systems for the rapid exchange of meteorological and related information.

International coordination for the establishment and maintenance of climatological stations as well as the collection, processing, archiving and dissemination of climatological data and information is done by WMO. Furthermore WMO issues standards and recommended practices for the establishment and maintenance of climatological stations as well as for the exchange of climate data and products. These standards and recommended practices are available in the WMO technical regulations and guides to climatological practices.

In order to coordinate climate data management across African's NHMSs and regional/international bodies a framework similar to the WMO-GFCS could be proposed:

(a) To have a common **User Interface Platform** to provide a means for users, user representatives, climate researchers and climate service providers to interact;
(b) To have **Climate Services Information System** to protect and distribute climate data and information according to the procedures agreed by governments and other data providers;
(c) To upgrade/maintain **Observations and Monitoring** components to ensure that the climate observations necessary to meet the needs of climate services are generated;
(d) To conduct **Research, Modeling and Prediction** to promote the needs of climate services within research agendas; and
(e) To have **Capacity Building** component to support systematic development of the necessary institutions, infrastructure and human resources.

Drawing up functional schemas between the different NMHS's stakeholders within a data management operation including internal, national and international levels are especially useful. It facilitates a clear representation of all of the interactions and assists in the correct design of a network. Data flow from the observation location to the products intended for the users is particularly suited to this kind of schema. Such design could be extended to other topics like functional schema on the desired data operation or on the desired data access (Fig. 3).

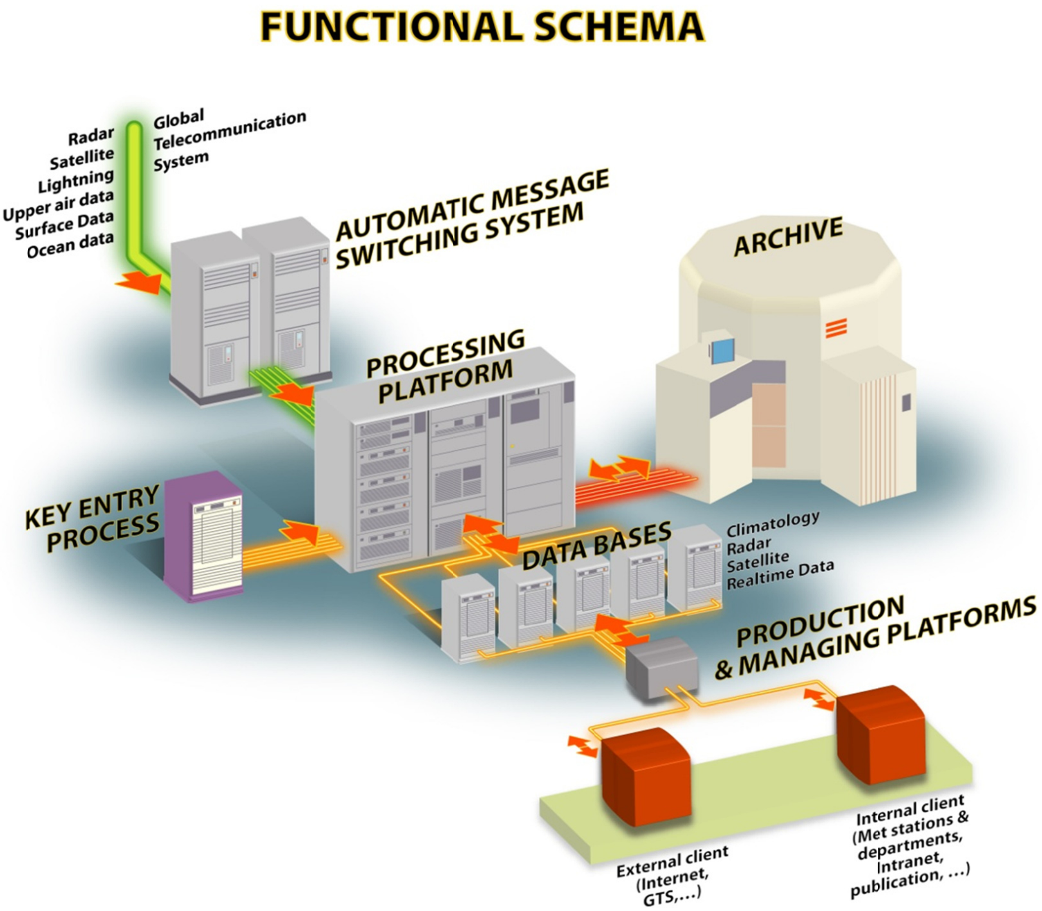

Figure 3: Example functional schema showing data flows and the various interactions at play within a data management operation (Plummer et al., 2003).

4. STRATEGIES FOR DATA RESCUE AND FILLING DATA GAPS

4.1 The Problem

The importance of historical climate data cannot be overemphasized. Long-term, complete, and quality-controlled climate time series are critical in many applications. These include:

- Understanding climate variability and trends and placing current observations into historical context;
- Assessing climate-related baseline or static risks;
- Modeling climate and its impacts on different socio-economic activities;
- Improving predictions at different time scales;

- Calibrating observing systems (e.g., Satellites, Radar) and validating related data;
- Downscaling climate projections and tailoring climate information for users;
- Assessing the performance of forecasting systems; and
- Index insurance applications.

Quality historical climate time series are critical to understand the natural variability and detect changes in the climate system at different time scales. Long-term climate time series are also very important in activities such as agricultural planning and water resource management. For instance, levees, dams, and reservoirs engineered on the basis of short climate records could result in inadequate flood or drought protection (Tan et al., 2004). Agricultural calendars designed decades ago with past climate data are no longer valid today and require urgent updates with data of the current climate to reduce weather related failures of food production.

The state of the in situ climate observing system in Africa is seriously inadequate, with the number and quality of weather stations in many parts of the continent in decline (Washington et al., 2006). The available stations are unevenly distributed with most of the stations located along the main roads. Communication failures have also been identified as a hindrance creating large data gaps in national, regional and global datasets. These impose severe limitations to the availability of climate information and services particularly to rural communities where these services are needed most. Where observations are taken, they suffer from gaps and poor quality. Some of the observations have also not been digitized or are stored on older electronic media that may not be used any more (Tan et al., 2004). These data risk being lost due to rapid deterioration of the medium. Data on papers may even get discarded as paper-based records take up office space. Thus, the undigitized data need to be rescued and digitized, while steps should also be taken to fill spatial and temporal gaps in climate observations. Some efforts have been made in both fronts. This section will summarize some of the existing efforts and propose what more is needed to be done.

4.2 Data Rescue

Data rescue involves preserving data at risk of being lost due to deterioration of the medium and converting past and current data into computer compatible digital formats for easy access and use (WMO, 2004). This is *a*n ongoing process of preserving all data at risk of being lost due to deterioration of the medium or the medium becoming obsolete. *S*torage medias need to be reviewed and updated regularly to maintain readability into the future. WMO recommends two approaches as to where the rescue process should be done. The first option is within the country where the data to be rescued are stored, while the second approach is to collect the data to be rescued at one location such as regional climate centers where the capability exists (WMO, 2004).

4.2.1 Past and Existing Efforts

There have been a couple of data rescue efforts undertaken for African climatological data. The main efforts are those undertaken by WMO with funding and technical support from the Belgium government. The first of these efforts was the WMO-Belgium Data Bank project. It run from 1979 to 1988, and covered nine countries in West Africa. This project produced 415 microfilms and 22,616 microfiches (WMO, 2008) .The second project, called DARE I (Data Rescue for Regional Association I), was launched in 1989 and lasted in 1997. It covered 42 countries in Africa, and produced 69134 microfiches and more than 1700 microfilms (WMO, 2008). The original microfiches of both these projects are kept at the Royal Meteorological Institute in Brussels. Copies of the whole set are also stored at ACMAD. The ACMAD has taken over the DARE I project starting from July 1997. A new DARE strategy has also been put in place to take advantage of the technical advances of the 1990's that made it possible to optically scan climate data as a new method of creating digital climate archives. This has permitted the data not only to be preserved, but also to be in a form for exchange via computer media (WMO, 2009).

The other effort is National Oceanic and Atmospheric Administration's (NOAA's) Environmental Data Rescue Programme of 1999, which has data in PDF and TIFF formats. NOAA has also been working with some African countries through a project called the NOAA African Upper Air Data Rescue project (AUADARE). NOAA's National Weather Service (NWS) has also provided funding to assist some NMHSs in eastern and southern Africa to retrieve climate data stored in formats that are not compatible with modern archiving and processing facilities. NOAA has continued similar activities through its International Environmental Data Rescue Organization (IEDRO). The IEDRO has rescued 1.5 million historic weather records worldwide. Most of these data have been digitized and entered into the World Weather Data Base operated by NOAA's National Climatic Data Center (IEDRO, 2010).

4.2.2 What Needs to Be Done for Going Forward?

In order to ensure that the work of data rescue in Africa is maintained at a sustainable pace the following issues need to be observed:

- **Make inventory of data that need to be rescued - t**here are still a lot of data that need to be rescued, particularly different weather maps and charts. Countries need to make the inventory these data and devise mechanisms to rescue and digitize them;
- **Look for more rescued data elsewhere - t**here are some African climate data available outside Africa in different formats. For instance, it has been reported that Italy has data from some African countries on papers going back to 1925 (WMO, 2008). These data sets need to be collected, organized and digitized;
- **Digitize data on microfiches -** ACMAD now holds an impressive amount data from many countries in Africa on microfiches. The storage of the microfiches will reduce the likelihood of loss or deterioration over time. This is very important for preserving data; however, to be useful the microfiches should be converted to digital formats. This could be a done using microfiches scanners. However, ACMAD may not have sufficient human and financial resources to do this (WMO, 2009). Thus, ACMAD's capacity needs to be built so that microfiches are digitized on a timely manner. Some of these microfiches are also available within individual countries. Though it makes more economical sense to digitize the microfiches at ACMAD, individual countries should also have the option to digitize their own microfiches;
- **Make data rescue an ongoing process -** data rescue is not something that is done just once but it is a continuous process. Storage medias need to be updated as technology changes and back up services should be set up. Thus, NMHSs should be helped to update their data storage media regularly. The NMHS should also have basic utilities for imaging records on paper that could be used as reference later on.

4.3 Filling Data Gaps

There are two types of data gaps. Spatial gaps are a result of sparse station distribution while temporal gaps are due to interrupted observations or lost data due for example to communication problems. Both gaps need to be filled to have spatially continuous and temporally complete climate time series. One approach to do this is combining observations from all available meteorological stations with global products such as satellite proxies and climate model reanalysis data. The main advantage of the global products is their excellent spatial converge at increasingly improved spatial and temporal resolutions. Satellite rainfall estimates now go back 30 years and reanalysis products can go back even further. The global products do suffer from some shortcomings that include poor accuracy particularly at higher temporal and spatial resolutions. Combining the two data stets helps to overcome the spatial and temporal gap in stations observation while improving the accuracy of the global products (Fig. 4). This will alleviate the inadequacy of climate data, particularly for rural Africa.

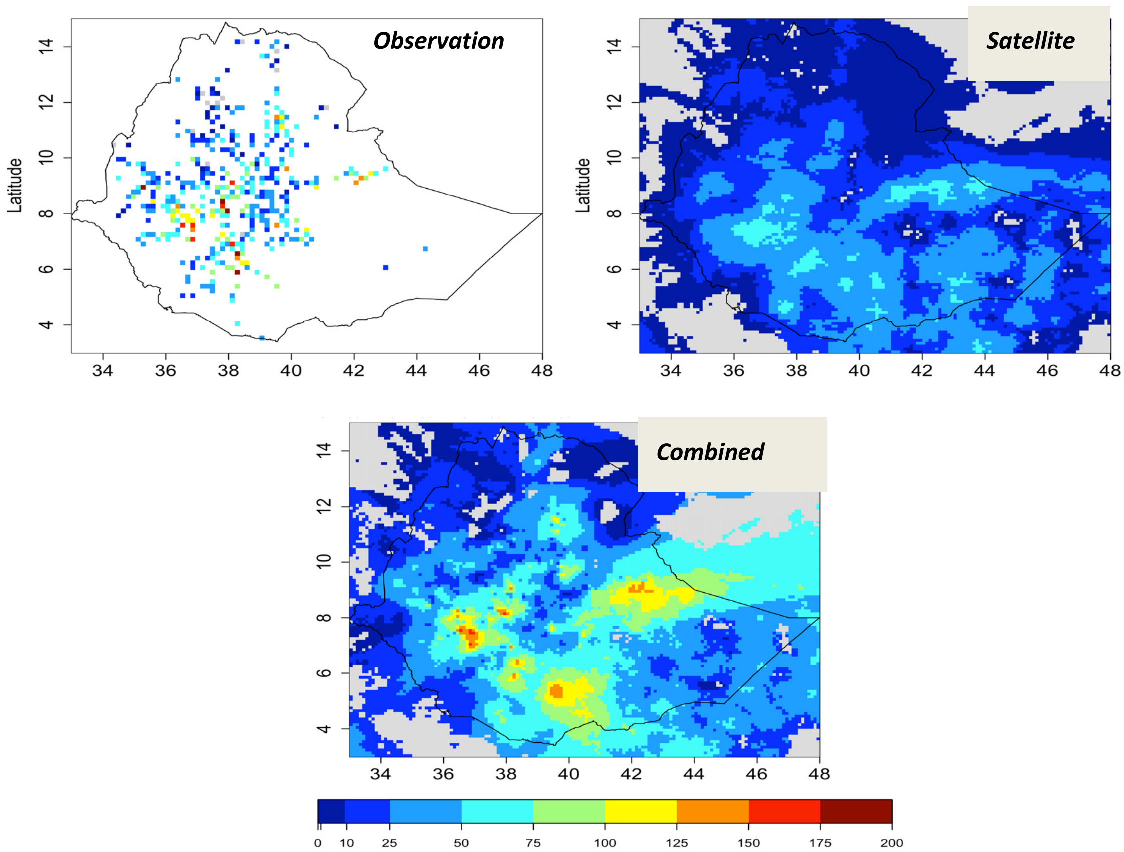

Figure 4: An example for combining rain gauge observations (top left) with satellite rainfall estimates (top right) to generate a combined product for Ethiopia.
The rain gauge observation has a lot of gaps while the satellite product mostly underestimates rainfall amounts relative the rain gauge measurements. The combined product overcomes the inadequacy of the rain gauge coverage and the underestimation by the satellite product.

4.3.1 Current Efforts

The National Meteorology Agency (NMA) of Ethiopia, in collaboration with the International Research Institute for Climate and Society (IRI), has implemented the above approach to generate 30-year time series of rainfall and temperature data at ten-daily time scale and for every 10km grid over the country. The combined rainfall dataset draws on more than 600 rain gauge stations merged with 30 years of satellite rainfall estimate. For temperature, data from over 300 stations are combined with MODIS (Moderate Resolution Imaging Spectroradiometer) land surface temperature estimates.

Going Forward: Strategy for Scaling up the Ethiopian Experience

The Ethiopian experience would be a good model for filling data gaps. It should be improved and scaled up to all countries in Africa adapting it to the needs and circumstances of each country. Doing the work for another country will now be cheaper and faster because the raw satellite data obtained and processed for Ethiopia covers the whole of Africa. This could be implemented in phases as follows.
Phase 1: Strengthen the Ethiopian efforts and test the approach at a couple of other places.

The project in Ethiopia has already accomplished a lot. However, there are areas that need further work. These include generating specific products, estimating and communicating uncertainties on datasets, training users, and work on other climate variables and daily time scales. At the same, it would also be good to test the approach in a couple of other countries before taking it to continental level.

Phase 2: Develop rainfall and temperature time series at continental level

There is an urgent need for continental level quality climate time series. Most of the regional climate centers do not have access to enough data from the member countries. This has been a challenge for climate analyses and applications at regional and continental levels. Reasonably good rainfall and temperature time series could be constructed at continental level using observations only from a fraction of the national networks and satellite proxies. This may start with historical data from 1981 to 2010(to match satellite data) and should continue to be done operationally. This will require a lot of efforts and may be lead by ACMAD under a consortium for African data involving regional centers, NMHSs, WMO and donors. ACPC could play a critical role in winning the political will from the countries. The capabilities of ACMAD and the regional centers should also be strengthened to develop and optimize data assimilation or estimation tools, building and managing regional databases.

Phase 3: Scale-up to more countries

This would be replicating the experience from Ethiopian, and other test sites from Phase 1, to more countries in Africa.

Phase 4: Include other climate variables and generate daily time series

The climate time series generated in the previous phases, except for Ethiopia, would be rainfall and temperature (min/max) at ten-daily time scales. There are needs for (1) other climate variables such as relative humidity, potential evapotranspiration, solar radiation, etc; and (2) data at daily time scales. This phase will do this initially for few countries and then scaling up to more.

5. ROLES OF NEW INVESTMENT AND INITIATIVES INCLUDING CLIMDEV AND ACPC

It is clear that in Africa the state of the climate observation network, data telecommunication and management facilities do not meet the required standards as elaborated in the proceeding sections above. The struggle to improve these climate data issues has been going on but without much success. Therefore with the establishment of the ACPC and adoption of the ClimDev, the continent expects to see much development in addressing some of the above problems thus helping Africa move fast in addressing those issues of climate and development. African countries will be able to take climate issues at the highest level of their national agendas including national policies. The ACPC has three broad activity areas around which its work programme is defined. These are the (i) knowledge generation, sharing and networking that consist of research, knowledge management, peer learning, and outreach activities (ii) advocacy and consensus building and (iii) advisory services and technical cooperation, which comprise capacity mobilization, capacity building and technical assistance. The Centre is an integral part of the Climate for Development in Africa (ClimDev-Africa) programme, which is a joint initiative of the African Union Commission (AUC), the United Nations Economic Commission for Africa (UNECA) and the African Development Bank (AfDB). ClimDev-Africa through the ACPC is addressing the need for greatly improved climate information for Africa and to also strengthen the use of such information for decision making by improving analytical capacity knowledge management and dissemination activities.

Therefore ACPC as a continental body that is responsible of overseeing climate policy related issue must make sure that the climate information and products that are provided to policy makers are based from good data and good science. It will therefore be important for ACPC working with countries and other partners including regional climate centres such as ACMAD, ICPAC, AGRYHMET, and SADC–CSC work together to ensure the infrastructure for climate observation network, data management and communications are improved to meet the required standards. For this to, happen ACPC will need to facilitate the following issues:

- Coordinate with countries and carry out advocacy, at the highest level, for investing in sustainable short and long-term climate observation network and data infrastructure;
- Help in defining requirements for climate data for different applications and facilitate a means of implementing some of the identified gaps such as those by GCOS (2006);
- The ACPC should get involved in the generation of climate information and data as appropriate and can synthesize and disseminate the information which may support climate variability and change adaptation and mitigation measures. It should work on behalf of both users and suppliers as necessary and appropriate;
- ACPC should help ClimDev to see that it implements its objectives of ensuring that the application of climate information and products is realized by many African countries;
- ACPC should encourage free sharing of data and information between countries and networking of countries on issues related to climate observation network and data; and
- Carry out any relevant coordination roles as may be desirable by the African countries.

6. CONCLUSION AND RECOMMENDATIONS

Effective management of climate variability and change requires that climate information be used effectively in planning and operation and that climate risk be incorporated routinely into development decisions. In order for this to happen in Africa, the National Meteorological and Hydrological Services (NMHSs) and other climate services providers in the continent must work at strengthening the observational networks and enhancement of their capacity to produce and deliver the full range of climate services in support of sustainable development. ACPC as a continental body mandated to oversee climate related issues at a policy level in the continent, will have to work with all these players in order to ensure that countries realize the need to address climate issues in their policy and planning thus contributing to the national sustainable development.

The following are some of the recommendations that need to be considered by ACPC and its partners on addressing issues related to climate observations network and data rescue efforts in Africa:

- Climate data should be treated as public good and as much as possible disseminated to the public and international networks. The amount of data shared for international networks from Africa is minimal compared to the available data in the continent. This is important for ground validation of innumerous forecasting early warning models, varying remotely sensed data which in many cases is used to fill the data gaps especially in remote rural areas of Africa, reconstructing missing information and enhancing the development application of climate data;

- It is believed that large sets of climate data are shelved in many parts of Africa's NMHSs as may be witnessed when people request data for research. People are given hard copies which they use to develop their own soft copies. Countries with support of international organization should rescue the data and incorporate it as part of their national, regional as well as global climate network. It is more useful when incorporated into the global network than being left decaying in shelves of a Meteorological Service Offices;

- Reverse the deteriorating stations in climate networks. It is usually easier and useful quick fix to renovation and to maintain dilapidated stations than installing new stations. It supports reconstructing historical data and can be used in conjunction with new data generated from newly installed stations. Therefore, reinvigoration of African Network requires both sustainable maintenance as well as installations of observation stations which have automatic nature and can be easily integrated with remotely sensed data. This also requires improvement in data management and archive systems;

- ACPC should coordinate with sub-regional economic communities and countries and carryout advocacy, at the highest level, for investing in sustainable short and long-term climate observation network and data infrastructure. It should also help in defining requirements for climate data for different applications and facilitate a means of implementing some of the identified gaps such as those by GCOS (2006);

- The ACPC may get involved in the generation, synthesize and disseminate of climate information in support of adaptation and mitigation measures, but shouldn't be generating climate data itself. It should also support the user community to understand, demand and use climate information;
- Follow up is required to fulfill previous promises made of installing newly required climate stations. The installation of new stations that combine future benefits (once the station has been

running for many years) with immediate benefits such as calibrating satellite data or cross referencing with other data source (e.g. streamflow) is important;

- The principles of a framework like the WMO GFCS would be well placed to coordinate climate data management and observations network across Africa. Furthermore strengthening Regional Climate Centres will improvement management regional data banks;

- Make inventory of data that has been rescued and that need to be rescued **- t**here are still a lot of data that need to be rescued, particularly different weather maps and charts. Countries need to make the inventory of these data and devise mechanisms to rescue and digitize them. Make data rescuing an ongoing process **-** data rescue should not be something that is done just once but need to be a continuous process;
- Devise new approaches in filling data gaps using combined observations from all available meteorological stations with global products such as satellite proxies and climate model reanalysis data; and
- NHMSs should enter into partnerships with other non-governmental institutions including relevant private sector to improve their observational networks while they the NMHSs remain the custodians of the data.

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