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Review of meteorological/climate data sharing policy (WMO Resolution 40) to promote their use to support Climate Information Services uptake in the African continent

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WISER
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ACPC
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Prepared by Mouhamadou Bamba Sylla (WASCAL Competence Center, Ouagadougou, Burkina Faso, syllabamba@yahoo.fr, sylla.b@wascal.org)

With contributions from Yosef Amha, Frank Rutabingwa, Charles Muraya, Bruk Teki, Stephen John Mututi, John Mungai, Benjamin Lamptey, Helen Kuria, Mariane Kane Diop, Eshete Dejene, Eric Asuman, Mduduzi Sunshine Gamedze, Seydou Traoré, Nestor Nianga Nkufi, James Ngoma, Ismael Lutta Mulama, James Kivuva

List of Acronyms

ACMAD African Centre of Meteorological Application for Development
ACPC African Climate Policy Center
AGRHYMET AGRrometeorology, HYdrology, METeorology Regional Center
ASCII American Standard Code for Information Interchange
CLIMSOFT CLIMatic SOFTware
CIS Climate Information Services
CR4D Climate Research for Development
CSV Comma-separated values
ECPAC Climate Prediction and Application Centre
GFCS Global Framework for Climate Services
GHACOF Greater Horn of Africa Climate Outlook Forum
GRIB GRIdded Binary or General Regularly-distributed Information in Binary form
GTS Global Telecommunication System
ICPAC IGAD Climate Prediction and Application Centre
IGAD Inter-Governmental Authority on Development
IPCC Inter-Governmental Panel on Climate Change
NARCC Northern Africa Regional Climate Center
NetCDF Network Common Data Form
NMHS National Meteorological and Hydrological Service
PRESAC Prévisions Climatiques Saisonnières en Afrique Centrale
PRESAGG Prévisions Climatiques Saisonnières pour les pays du Golfe de Guinée
PRESANORD Prévisions Climatiques Saisonnières en Afrique du Nord
PRESASS Prévisions climatiques Saisonnières en Afrique Soudano-Sahélienne
RCC Regional Climate Center
RCOF Regional Climate Outlook Forum
REC Regional Economic Commission
SADC-CSC Southern African Development Community – Climate Service Center
SADC-DMC Southern African Development Community – Drought Monitoring Center
SARCOF Southern African Regional Climate Outlook Forum
SWIOCOF Southwest Indian Ocean Countries Climate Outlook Forum
UNECA United Nations Economic Commission for Africa
WIS WMO Information System
WMO World Meteorological Organization

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Executive Summary

In this report, we review the World Meteorological Organization (WMO) resolution 40 on policy and practice for the exchange of meteorological data and products that regulates the international data sharing. This is done on the context of Africa and to support Climate Information Services (CIS) development for a sustainable climate change adaptation and resilient development of the continent. In the application of the resolution, WMO member countries share “essential” data and products with each other and with research and educational settings in a “free and unrestricted” basis. However, members include more conditions in sharing the “additional” data including charging for it to the private sector and for commercial activities. The resolution allows the possibility of other policies to co-exist. In this regard, ICPAC is implementing a data sharing policy with NMHSs in countries of the Greater Horn of Africa; AGRHYMET with countries in West Africa and SADC-CSC with countries in Southern Africa. ECPAC will soon do so with countries in Central Africa. In the northern part of Africa WMO implements a distributed regional climate center system where all NMHSs participated.

Some best practices at continental, regional and national levels are highlighted. At the continental level, WMO runs a data management facility known as WIS for automated collection and dissemination of weather and climate data through GTS. All data from the African NHMSs and the data production centers are gathered at the hub of Casablanca, Morocco for global redistribution and exchange. At the regional, best practices include the RCOFs and the data repositories of the regional centers. In fact, during RCOFs, all member countries share their data, tools and methodologies, to develop a climate information consensus for the next rainy season, identify the impacts and implications, formulate response strategies and widely disseminate the results. For the repositories at the regional centers, the database is populated by data from the relevant NMHSs which are further quality controlled and processed to generate tools and products. These enhanced data and products are shared back with the country members to support their activities.

At the national level, most NMHSs maintain good relationship with universities, research scientists and private sector. Data requested in most of the cases is supplied under some conditions. A recent best practice is the inclusion of the relevant NMHSs in research and service projects, securing thus data and products exchange between the investigators (e.g.

research centers, NMHSs, etc.). Finally, for the execution of the national plan for disaster risk management, many African countries are strengthening the political and institutional coordination, substantially improving work relationship, data and information co-development and exchange between the different national and technical institutions, companies and users.

There are still some barriers for an efficient data sharing in Africa. Strategic barriers include an absence of legal obligation in the WMO resolution 40 which recognizes the country member's right to choose the manner by, and the extent to, which they make data and products available domestically or for international exchange. Another strategic barrier has to do with user's malpractices and misappropriate data exchanges that prompt many NMHSs to withhold and protect their data. National laws and legislation also restrict access simply because of national attitude and protectionism or, more seriously, when considerable concerns about national security exist for the data requested for certain areas. Finally, governments lack a proper understanding of the value of data sharing and tend to consider weather and climate data as commodities and focus in developing various restrictions and charges for it to support the costs of the infrastructure and/or equipment and to control the competition from others.

At the operational level, some data providers lack sufficient human and technical resources. Also, some concerns about data quality and public scrutiny over it can make them reluctant to share. In addition, data discovery and access is a key operational barrier. In fact, it is often difficult to determine whether data needed for a specific region exists as most of it is not published online. Even if the existence is established, semantics, meanings and clear requirements for access are often missing. This can prevent the existence of a common data format and interoperability challenging thus an efficient data sharing process within the region. However, WMO is addressing these issues through the implementation of the WIS system and CLIMSOFT.

Based on the above premises, some recommendations are provided. They include a revision and improvement of the WMO resolution 40, an extension of the WIS to all data providers, an engagement between data providers and receivers through a business model for a win-win relationship, the harmonization of the technical aspects for data discovery and access and finally the extension of the East African data monitoring meeting to the

whole continent. In particular, the WMO RCCs must be strengthened and the policy coordination more effective with the support of ACPC/CR4D. Finally, we suggest the creation of a data sharing department within an operational institution with a continental mandate, e.g. ACPC, ACMAD, WMO regional office, etc.). This institution should be governed by a board of head of African states providing public support. Its role would be to develop policies, regulations and guidelines to promote data sharing and enable open access data culture within the continent. It would seek donor commitment and secure funds to support countries' equipment maintenance and data collection. At the daily basis, it could oversee the data exchange activities, provide clearance for all research and or/service projects coming to Africa, settle and resolve issues raised by a member through filed complaints and based on legally approved modalities.

1.0 Introduction

1.1. Setting the scene: climate information services

Climate change constitutes a serious threat to many development sectors (including but not limited to agriculture, water, energy) in Africa (IPCC 2014; Sylla et al. 2016; UNECA 2017). To face the adverse impacts of a changing climate, adaptation has become a prominent process in the continent. Adaptation can be incremental when coping with current climate variability or transformational when adjusting to more severe impacts of climate change further in the future (Howden et al. 2012). While the latter builds on long-term climate change projections, the former requires day-by-day or season-by-season information.

Climate Information Services, involving the generation, packaging and delivery of weather and climate data and its subsequent uptake by users is then rapidly expanding in Africa to support climate adaptation and resilient development (Kadi et al. 2011; UNECA 2011). CIS can describe historical, current and future weather and climate conditions and can entail future predictions on daily, monthly, seasonal or decadal timescales and projections at multidecadal and centennial scales (WMO 2014a). It also takes into account their impact on natural and human systems. In Africa, traditional CIS developers/providers are the National Meteorological and Hydrological Services (NMHSs) whose activities are supported by a network of weather stations taking measurements of, among other parameters, precipitation and temperature under the guidance of the WMO. As there are various types of CIS, there are also various sources of providers ranging from national institutes to regional research centers as well consultancy firms, national associations, insurance companies and private sector.

1.2. The need of data sharing for CIS

CIS providers do not necessarily generate their own weather and/or climate data. They can make use of available data from other owners/providers and add value (knowledge and expertise) to develop and provide the information needed by specific users (Feinstein and Llovet 2014). The data needed to monitor and predict weather and climate, to develop tools and generate products in the framework of CIS are mostly owned by the NMHSs. In addition, the monitoring and forecasting of severe weather events (i.e. extreme events as

tropical cyclones, Mesoscale convective systems, etc.) as well as the development of tools requires data beyond the national boundaries (Snow et al. 2016; WMO 2014b). Finally, the research centers and the private sectors have strong technical expertise and means to develop tools and add substantial value to the data generated by the NMHSs. Data sharing standards and procedures have then to be developed to regulate exchange of data between the different member countries in one hand and in the other hand between members, regional research centers and others non-governmental companies. Such data exchanges are key for enabling environment for a successful co-production process of CIS for public safety.

1.3. Examples of data sharing standards

To date there are a number of data sharing policies regarding exchange of hydrometeorological data as far as Africa is concerned. They are the WMO Resolution 40 (Cg-XII, 1995) on policy and practice for the exchange of meteorological and related data and products including guidelines on the relationships in commercial meteorological activities, the WMO resolution 25 (Cg-XIII, 1999) on Exchange of Hydrological Data and Products and the WMO resolution 60 (Cg-17, 2015) on policy for the international exchange of climate data and products to support the implementation of the Global Framework for Climate Services (GFCS). In Africa at the regional level, these data sharing standards co-exist with policies between the regional climate centers of each economic commission and the relevant NMHSs. For example, the Inter-Governmental Authority on Development (IGAD) Climate Prediction and Application Centre (ICPAC) based in Nairobi, Kenya is implementing a data sharing policy with NMHSs in countries of the Greater Horn of Africa; AGRrometeorology, HYdrology, METeorology (AGRHYMET) regional center based in Niamey, Niger is doing the same with countries in West Africa and Southern African Development Community – Climate Service Center (SADC-CSC) with countries in Southern Africa. Recently, (ECPAC) is created to act as a regional climate center and will thus implement a data sharing policy with countries in Central Africa.

Among all of these, the one guiding principal for international exchange of meteorological data and products is the WMO Resolution 40.

2.0 Objectives of the review

The general objective of the review is to assess hydrometerological (including climate) data sharing standards and procedures in Africa (under WMO Resolution 40) to facilitate CIS production and help boosting their uptake over the continent. To achieve this, a number of specific objectives are defined. These include the following:

- Reviewing current practices of data exchange under the WMO Resolution 40
- Identifying best practices and success stories
- Highlighting challenges to data sharing
- And ultimately providing recommendations about data sharing to promote their use to support CIS uptake in the African continent

3.0 Current practices in data sharing – the WMO Resolution 40

3.1. What's in the WMO resolution 40

WMO Resolution 40 (Cg-XII, 1995) entitled "policy and practice for the exchange of meteorological and related data and products" regulates the international data sharing. In summary, this policy stipulates that: all members (primarily NMHSs) shall provide on a free and unrestricted basis **essential** data and products required to describe and forecast accurately weather and climate, necessary for the provision of services in support to the protection of life, property and the well-being of all nations. These **essential** data defined as a minimum set at the annex 1 of this resolution include but not limited to surface synoptic data, all available in situ observations from the marine environment and all reports from the network of stations recommended by the regional associations (i.e. Africa, Asia, South America, North and Central America, South-West Pacific and Europe) as necessary to provide a good representation of climate. In terms of satellite data, it is stated that it concerns those data and products from operational meteorological satellites that are agreed between WMO and satellite operators and necessary for operations regarding severe weather warnings. These satellite operators can be public entities, private sectors and/or intergovernmental agencies.

Free and unrestricted is here defined as non-discriminatory and without charge. In the context of this resolution, without charge refers to avoid charging for the data and products

themselves, and to limit charges to the cost of reproduction and delivery. The resolution also focuses on provision of data under the above conditions to the research and education communities (researchers, teachers and students in academic and research institutions) for their non-commercial activities.

Commercial (i.e. recompense beyond the incremental cost of reproduction and delivery) activities may be subject to different policies and approaches. In fact, the resolution urges members to share **additional** data and products which are required to sustain WMO programs at the global, regional, and national levels and to further assist other members in the provision of meteorological services in their countries. In this case, some conditions on their re-export (redistribute, physically or electronically) for commercial purposes may be justified for reasons such as national laws or costs of production. In this regard, it is stated that the resolution recognizes the right of governments to choose the manner by, and the extent to, which they make data and products available domestically or for international exchange. Research and education community commercial activities are subject to the same conditions.

3.2. Application of the Resolution

WMO Resolution 40 was put in place to secure free and unrestricted international exchange of meteorological/climate data in order to permit all members to generate forecasts and warnings for the provision of services. Because of the fact that members are defined here as countries, the resolution applies not only to NMHSs but also extends to other national and intergovernmental weather networks. It is clear that this resolution acknowledges the importance of sharing data as a key to understand climate, study extreme climate and severe weather events to provide early warnings and in general to help communities adapt to climate change by providing climate services. It also highlights the dependence of the research and education communities (many of which provide climate services) on access to meteorological and related data and products but also the existence of a trend towards the initiation and/or increase of commercial activities of many NMHSs and the private sector.

In applying the resolution, members upload every 3-hours essential data to the WMO Global Telecommunication System via the regional hubs which in turn will be made available for sharing worldwide.

While this resolution is a big step forward for a free and unrestricted international data exchange, its effectiveness mostly depends on the willingness of the member country. In fact, no legal mandate requires the members to comply with the resolution and there is no consistent application of this policy among them. The latter results in a tendency to strictly or flexibly interpret the resolution and is mostly left to the discretion of the members. For example the term **"All available"** means that the data provider can make them available (or not) under this resolution. Another example is the fact that the resolution recognizes "**the right of Governments to choose the manner by, and the extent to, which they make data and products available domestically or for international exchange**", giving the members the possibility to deny access due to so called national policies and legislation.

In interpreting the resolution, it is also important to highlight the distinction between **essential** and **additional** data. In the context of observational data for weather and climate applications, there may be different perceptions of the word **essential**. Some users (e.g. research centers, climate service providers etc.) often perceive it as the data most critical for their application (e.g. the data streams with the highest impact on forecast skill of a Numerical Weather Prediction, Seasonal Forecast and/or Climate models"); others, mainly data providers, often denote data **essential** if they are being distributed in an open manner, with no limitations on use, free of charge (WMO 2016). In any case, this resolution allows the possibility of different data sharing policies to co-exist among members. The most important outcome of this is the competence of a NHMS to define which of their data are made available under **"essential data"** (as only a minimum is explicitly suggested) and which set is **"additional data"**. While the members with a data sharing policy favoring unrestricted and free of charge access declared all their data **essential**, others with more restricted policies, allow commercial distribution of some data of their choice (termed as **additional**) while declaring other data as **essential**. This is a serious issue for data sharing towards a better CIS uptake as the requirement for climate services is more extensive than the data covered by this resolution.

While the resolution created **essential** and **additional** data concepts as a mechanism to discourage commercial weather activities from the private sector, one unfortunate consequence is the focus on charging for the data. This has led to a limited amount and quality of data available for researchers, forecasters and modelers jeopardizing thus their ability to develop and refine tools and products for better CIS development and uptake.

The resolution did not provide guarantee for equal and timely access to the data for all CIS providers, did not address the issue of pricing and did not limit the commercial activities of the members.

4.0 Best Practices / success stories

4.1. Continental level

At the continental level, typical best practices/success stories involve the WMO Information System (WIS) that replaces the Global Telecommunication System (GTS).

Under the WMO resolution 40, member countries (mainly NHMSs) upload observed data every 3-hours into the WIS. The WIS supersedes the Global Telecommunication System (GTS). WIS is a coordinated global system of telecommunication and data management facilities designed for routine collection and automated dissemination of observed data and products in support of all WMO Programmes. It also allows a better data discovery, access and retrieval of all weather and climate related products and information generated by the different centers. *WIS uses* a hierarchical structure on three levels by operating three types of centers: Global Information System Centres (GISCs), the Data Collection or Production Centres (DCPCs) and the National Centres (NCs). The NC (former National Meteorological Centers) is responsible for collecting and providing weather and climate data and products for global and regional distribution to their responsible GISC or DCPC, as well as distributing data at the national level. Similarly, DCPC collects or generates sets of data, forecast products, processed or value-added information, and provides archiving services for the NCs. Finally, GISC, connected to both NCs and DCPC under its responsibility, serves as global collection and distribution centers for routine global dissemination of data, products and information. It is important to note that most of the DCPCs are former Regional Specialized Meteorological Centers or Regional Telecommunication Hubs that were responsible of centralizing the collected data in their region of interest before sharing

it with World Meteorological Centers (WMCs). Likewise, GISC are mainly former Regional Telecommunication on the Main Telecommunication Network or World Meteorological Centres that had a role of archiving weather and climate data for global re-distribution. In Africa, while all the NMHSs act as NCs, only 8 countries namely Algeria, Egypt, Congo/Brazza, Morocco, Kenya, Niger, Senegal, South Africa host DCPCs (1 or more centers). All these DCPCs along with the different NCs are connected to their principal GISC located in Casablanca (Morocco) that centralizes all the African weather and climate data and related products and information for global exchange.

It is worth mentioning that ACMAD have helped some countries to rescue their data. In fact, most of these historical data were stored in paper records. These paper records can deteriorate with time and jeopardize the country's ground truthing history. ACMAD supported thus these countries to save these datasets in microfiches first and then to digitize them. In addition, many times, this institution has also supported some regions to organize their seasonal prediction forums. For both activities, ACMAD stores a copy of the collected and rescued data in their database. These activities are undertaken at different countries regardless of the region of interest and thus constitute a best practice/success story at the continental level.

4.1. Regional level

At the regional level, there are two best practices/success stories that need to be highlighted:

The regional climate data repositories

In Africa for each regional economic commission, there is an inter-governmental regional center dealing with hydroclimate issues and working closely with the NMHSs. They are AGRHYMET for West Africa, ICPAC for East Africa, SADC-CSC for Southern Africa, ECPAC for Central Africa and the NARCC network in Norther Africa. They produce and disseminate meteorological, environmental and hydrometeorological information to help improve disaster risk reduction in the region.

To fulfill their mandate, these centers acquire climate and remotely sensed data; quality control and process the data to develop basic statistics including climatological baseline and extreme events occurrences; monitor, predict and provide early warning information

about high impact weather events over the region; develop tools and maintain national and regional databases and information systems required to address vulnerability and risk reduction; and ultimately support the climate resilient development of relevant sectors through research and applications. To implement these activities, each regional center operates a data repository populated mostly by data from NMHSs of the region and the products generated from it. This is made possible through a data sharing policy that each center has co-signed with NMHSs of the region. The policy is strengthened by the public support from head of states (that are the actual members of the governing board) and subsequently from the relevant ministers and director generals. This public support urges and eases the member country to comply with the terms of the policy.

On regular basis, the countries process their raw data and share it with the relevant regional center. For example, at ICPAC, this is done every 10 days. The centers in turn further quality control the data, process it and generate tools and products that are shared back with the country members. At ICPAC, database is also generated for digitized data that combines these data and remotely sensed data. But data management is a major problem for nearly all regional climate centers. In fact, sometimes it happens that a country's hydroclimate data storage crashes and some or all the data gets lost. The regional center then supplies the country with its data and therefore acts as a data backup as well. This practice substantially improves data and information exchange between the countries and the regional centers and should be extend to others research and service centers/institutions within the relevant region.

The Regional Climate Outlook Forums (RCOFs)

RCOFs produce consensus-based and user-relevant climate information and products to support development sectors such as water resources and agriculture for the coming season. Currently, there are up to seven regional climate outlook forums in Africa. The on-going RCOF activities in Africa are coordinated by the WMO designated regional centers namely ACMAD, ICPAC, AGRHYMET, and SADC-CSC. Efforts to establish regional centers namely ECPAC in Central Africa is ongoing.

AGRHYMET, based in Niamey, is coordinating two RCOFs: they are the Regional Climate Outlook Forum for Sudano-Sahelian Africa (with a French acronym: PRESASS) covering

17 countries in West and Central Africa and the Regional Climate Outlook Forum for the Gulf Of Guinea Countries (with a French acronym: PRESAGG) covering countries at the Coastal Atlantic region of West and Central Africa.

ACMAD, located in Niamey as well, is currently supporting two others: The Southwest Indian Ocean Countries Climate Outlook Forum (SWIOCOF) that covers island countries in the southwest Indian Ocean and southern Africa adjacent countries and the Regional Climate Outlook Forum for Central Africa (With a French acronym: PRESAC) covering countries in Central Africa including Sao Tome and Principe.

The Greater Horn of Africa Climate Outlook Forum (GHACOF) is coordinated by ICPAC based in Nairobi, Kenya and covers eleven countries namely Burundi, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Somalia, Sudan, Tanzania and Uganda. While the Southern African Regional Climate Outlook Forum (SARCOF) is coordinated by the SADC-CSC based in Gabarone, Botswana, and covers all 14 SADC member states (i.e. Angola, Botswana, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe).

It is important to note that the Regional Climate Outlook Forum for Northern Africa (with a French acronym: PRESANORD) consisting of the five countries in North Africa has joined the South-East European Climate Outlook Forum (SEECOF) to form the Mediterranean Climate Outlook Forum (MedCOF), coordinated by the State Meteorological Agency of Spain (AEMET), with the contribution from ACMAD.

RCOF was initiated by WMO, NMHSs, regional climate institutions and other international organizations to provide consensus based early warning seasonal climate information for reducing climate-related risks and to support sustainable development efforts of some specific regions. RCOFs bring together climate scientists, policy makers and the general user community to develop warnings of potential impacts of the climate on various socio-economic sectors.

The production of the hydroclimate information and products during RCOFs is achieved through regional cooperation and partnership and the implementation is tailored to meet the local conditions and communities. Each forum gathers all NMHSs, RCCs, regional and international climate experts, representatives from the user sectors, private sector and the

media. They share their data, tools and methodologies, develop a consensus for the regional climate outlook, identify impacts and implications and formulate response strategies. The dissemination of this information is key for the success of the RCOFs. In fact, at the end of each forum, a final communique' is produced, a press conference is hold with the media and the products published in relevant web portals. This constitutes an excellent practice in terms of data and products sharing over Africa. Although RCOFs take place all over the continent, the data sharing is limited to the regional level of interest.

4.2. National level

A common practice in many countries in Africa is that the NMHSs and some regional centers provide data to students, universities and research scientists involved in non-commercial activities. The majority of them do not charge at all any money for the provision of these data when the procedure is followed properly. If the need for data from specific location arises, a request is to be sent to the right data owner/provider which is most of time a NMHS. This latter will meet with and interview the person. At the end, a decision about whether to provide the data or not is made. If the data request is not for commercial activities, it is likely that it will be supplied. The provision of these data is done with some conditions that the user will have to comply with. Most of these conditions deal with not sharing data with third-parties, acknowledgement of the source of the data and/or co-authorship (i.e. working with someone at the data owner agency).

However, there are situations when the university and/or the research scientist are engaged in a fully paid consultancy work and/or the data is requested by/from an institution of the private sector. In these cases, the data owner charges for it. Most NMHSs see these charges as a contribution from the users in order to help fund the sustainability of the equipment, processing data and the observation networks.

In addition, climate scientists in Africa often carry out research activities that require climate data and/or weather forecasts for some locations within a country. These activities are part of service and/or research projects that are most of the time jointly developed and implemented with the relevant NMHS. As a full member of the project, the NMHS or any other data owner involved shares their data, products and information with all parties to

fulfill their common goals during the implementation phase. This is another best practice that needs to be promoted.

Finally, many countries in Africa are refining their national plan for disaster risk management in connection with the national framework for climate service. As a matter of fact, they are strengthening the institutional and political coordination at all levels to build functional early warning system and response strategy. In this regard, the extension of areal coverage, the development of relevant data, products and information as well as the formulation and the publication of information related to hydro-meteorological risks are of major concerns. This has prompted the creation of a multidisciplinary group in most countries gathering, among others, relevant technical structures (i.e. NHMSs, water resources departments, river basin commissions, etc.), users (farmers, livestock breeders, extensions, urban officials, red cross associations, etc.), media and insurance companies. An immediate result of this is the improved work relationship and coordination between the different national institutions in terms of data and information co-development and exchange.

5.0 Barriers to data sharing

5.1. Strategic level

Absence of legal obligation in WMO resolution 40 and lack of understanding

Resolution 40 was created as a middle ground for the conflicting policies on data sharing standards across the world (Yost, 2016). It calls for free and open data exchange up to some extent (WMO, 1995). However, there are no legal bindings. The resolution even recognizes the right of Governments to choose the manner by, and the extent to, which their data are shared. Therefore, the member is not forced to comply with any of the different clauses mentioned in the resolution and can thus decline requests for any reason of its choice without further contestation or appeal.

Many governments, NMHSs and other data providers withhold their data just because of a lack of understanding of the value of sharing. Many misses the fact that sharing data can save lives and properties and can expose potential inconsistencies and gaps in the exchanged data not expected by the owner.

Users malpractices and misappropriate data exchanges

Most of the data owners/providers attitudes to withhold data are response to receivers/users previous malpractices. In fact, various NMHSs and research centers have encountered many situations during which their data are exposed and published without their consent. In some cases, observed data are modified with used on WMO standard rules and procedures. Most of the offenders did not use official channels to acquire the data or even if they did, they did not disclose their real intentions. For example, some experts will request data pretending to use it for non-profit activities while engaged in a fully paid consultancy. Others (mainly professors and student supervisors) will send many students to request different datasets for different time periods and locations and at the end gather all the country and/or region's data for their commercial activities. It must be emphasized that data acquired from NMHSs are subject to some conditions including the fact that the data can only be used for the purpose it is acquired for and is not meant to be shared with third parties. However, there are users who will purchase part of the data and proceed to an informal exchange with other users who will expand and complete their database without the knowledge and/or consent of the data owners. Finally, some individuals/organizations will propose their help in digitizing weather records stored in microfiches while saving the data for their own purpose. These malpractices have prompted governments to withhold the data for the purpose of protectionism.

National laws and legislation

Most governments in Africa have passed laws to protect and restrict access to weather and climate data measured and collected by their NMHSs. Some reasons why these legal restrictions exist can be linked to considerable concerns about national security but also to national attitude and protectionism.

In fact, geospatial data can tell a lot about countries' strengths and weaknesses. For example, in Cote d'Ivoire, satellite and ground truth data from some regions at a particular period of the year can provide information about cacao yields. For some strategic reasons the government may consider this as classified information and restrict the circulation of such data to government and/or national institutions officials and not grant access to external users and/or stakeholders. Often these laws are cited as the reason why sharing

requests are denied without any real investigation as to whether it truly threatens national security.

Another reason why data requests are denied based on these laws has to do with conflict of interest. In fact, the NMHSs collect data, develop their own value-added products from the raw data and deliver services. Therefore, to deter any competitions and/or to have competitive advantages, they tend to deny any raw data requests under any conditions from any potential competitors.

This constitutes a serious threat to data sharing in Africa as some of the regional climate centers can request the country's data many times under their data sharing policy without any success.

Cost recovery of the infrastructure

Some CIS providers make information free of charge, others impose various costs and restrictions on certain information and some others are actively engaged in commercial activities. Based on these premises, among the NMHSs, interest in developing various restrictions and costs for their data has grown as means to enable governments to acquire funds for supporting the costs of the infrastructure (i.e. weather stations, transmission and storage and distributing network) and to control the competition from the private sector. In fact, for economic reasons, some governments in Africa provide inadequate funding on hydrometeorological data equipment and collection. While most of the equipment are acquired through assistance by WMO, World Bank and other international institutions and/or programs, other important issues remain unsolved due to lack of funding: their maintenance and the data collection. This can lead to deterioration of meteorological and hydrological observation networks, outdated technology, equipment and forecasting methods and poor quality of services. Data is then seen as a commodity that had economic value for the owners to sponsor the equipment maintenance and data collection. They have easily slid into charging for the data in a for-profit and even not-for-profit setting.

5.2. Operational level

Human and technical resources

Currently in Africa, data are shared globally via the WMO Global Telecommunication System (GTS) and regionally/locally via emails and/or external hard drives copying and/or

posting. Very few institutions provide data via a punctual File Transfer Protocol (FTP). In a process of data exchange, some additional processing (e.g. coding, running scripts, copying etc.) and additional resources (e.g. powerful machines, servers, large space disks, good Internet connectivity, etc.) are needed to make the data available for sharing or to access to someone's database. Many data owners and/or receivers lack some of these resources and/or staff to supply/receive the data. In addition, the data to be shared with WMO through GTS is done every 3 hours. Many NHMSs only supply these data during the day and not during the night because of lack of human and technical resources. Sometimes the information is acquired by the service after the deadline making it unable to be uploaded into the GTS system causing thus large missing data in the database. Another issue that needs to be highlighted is the connectivity between the WMO centers and the regional hubs. The regional hubs have a role of bridging the connection between the NHMSs and the World Meteorological Centers for global redistribution of the regional data. Many times, these hubs encountered some technical problems (e.g. the Kano hub) challenging thus the timely upload of real time data to the system. Therefore, human and technical resources in terms of both quality and quantity constitute a serious challenge to data sharing in Africa.

Data discovery, access and quality

To enable an efficient data sharing, first there is a need to be able to find out about the existence of the data. Often this is very difficult to determine, particularly database owned by NMHSs. While it is obvious that each African country operates an observation network, many users have no idea about whether the data needed for a specific region actually exist. To have this information, you need to know someone who has access to it.

Even when the existence of the database is established, other issues related to the actual characteristics (i.e. semantics and meanings) and history of the data (i.e. information about who collected them and under what authority) arise. This highlights the issue of the meta-data. In fact, most of the data owners store their database locally and do not publish the metadata online in a way that makes the data discoverable, intelligible and assessable.

Even when the metadata is published and accessible, clear requirements for access to the database are missing most of the time. Also, some concerns about data quality and public

scrutiny over it can make data owners reluctant to share. These have substantially undermined an effective data sharing in Africa.

Data format and interoperability

Some of the technical aspects relate not only to having standards for all these data quality measures, discovery and access but also a uniform and concise data format. Data formats used by data owners and/or providers are mostly ASCII (American Standard Code for Information Interchange), Excel spreadsheet, CSV (Comma-separated values), GRIB (GRIdded Binary or General Regularly-distributed Information in Binary form) and NetCDF (Network Common Data Form). All these formats warrant the possibility to share the data electronically.

It should be noted that there is still some information stored in microfiches and it mostly concerns the historical data from many African countries. These types of information raise another issue related to what language is used to report. Even when in a human-readable format, this information cannot be shared electronically unless digitized. However as explained above, there a number of data rescue and digitizing activities supported by ACPC and ACMAD in many African countries.

While most data owners in Africa store data in Excel spreadsheet and CSV formats, only few of them use GRIB and NetCDF notwithstanding the fact that the two latter are more concise data formats to store efficiently large historical and forecast weather data. When comparing various data owners/providers, their datasets in Excel and CSV format use different ways of reporting the same information with the columns and raws stocking different contents. For example, for some data providers, the columns can store information about the time steps (hours, days, months or years) and the rows the information related to the actual recorded parameter. Other data providers switch this arrangement.

Data stored in GRIB and NetCDF also encounter some issues with regards to their use in different systems. In fact, these data formats are prepared with their respective libraries linked to other libraries that help to manage, process, and store heterogeneous data. For interoperability (i.e. the ability of two or more systems or components to exchange

information and to use the information that has been exchanged), the libraries must match between the different systems.

It is worth mentioning that the above issues are being addressed by WMO through the implementation of the WIS system (as explained above) and CLIMSOFT (i.e. a software suite for storing climatic data in a secure and flexible manner and for extracting useful information from the data).

6.0 Recommendations

The recommendations provide some technical and conceptual principles required to promote hydrometeorological and climate data exchange in Africa for a better CIS development and uptake over the continent. All the recommendations provided here are independent from to another.

6.1. Revision and improvement of the WMO resolution 40 and extension of the WIS system

In improving the WMO resolution 40 to boost data sharing over the continent, a big step would be to get rid of the controversial denominations such as “essential data”, “additional data” as well as “all available data” that set path to an increasing commercial activity of NHMSs and limit the amount of data to be shared. These terms could be replaced by “all data currently collected or held” which is broader. In this regard, it is suggested that all data currently collected or held by the member should be shared upon requested as long as the request justified. Alternatively, an extensive list of minimum datasets including all those needed by the CIS community can be considered as “essential data”. In order to get a solid sense of the requirements of the community, this action may be preceded by an extensive survey of the CIS producers and/or providers (not only NHMSs but also national, regional, intergovernmental, international centers and private sectors).

In addition, a redefinition of “without charge” in “free and unrestricted is here defined as non-discriminatory and without charge” would be very beneficial to the promotion of data sharing. Ideally, “without charge” could refer to “free and open access”. Alternatively, it could mean avoid charging for the data and products themselves, and to limit charges to the cost of fulfilling user requests. This indicates limiting the charges to the cost of the

handling process and would apply in the case the data requires significant manual processing prior to exchange. WMO should provide pricing guidelines on this.

Furthermore, for a more efficient data exchange, a timeline should be defined in the resolution. This can be at the annual or monthly basis. Finally, the resolution should further encourage data owners to make free access (without any charge of any kind including cost of reproduction and delivery) for research centers and non-profit climate service providers. This would contribute to better innovation and economic growth within the region. However, for data exchange in the framework of a funded projects or commercial activities, some conditions may apply.

It should be emphasized that the WIS is a good model for data management, discovery and sharing. However, it should be extended to all regional and national research or service centers that operates a weather observation network and/or provide climate services free of charge within the African continent.

6.2. Data providers and receivers engagement through a business model

Business model is defined here as a practice that mutually benefits the data provider and the data receiver (i.e. a win-win relationship). The following recommendations are thus more indicated for data exchange between a regional research centers and a data provider (e.g. NMHS).

Regional research centers are encouraged by WMO to generate and deliver more regionally focused and better information and products including regional climate watch bulletins. In this case, a first business model would be the data provider shares their data with the regional research center which in turn helps in further quality control, adds value to the data, strengthens the NMHS capacities to meet national climate information needs and ultimately acts as a data repository and back up.

As most data providers apply charges to the data as means to acquire funds for supporting the costs of the infrastructure, another possible model could focus on helping to reduce these costs. For example, through third-party funding, the regional research center can provide infrastructure (automatic weather stations, transmission and storage equipments), help on the maintenance of the equipment and contribute to the quality control. It can also assist on data rescue and fund staffs training. Through this investment, the data provider

shares their data with the regional research center on an agreed frequency basis that could be near real-time, daily or monthly.

Funding agencies and planning organizations are further encouraged to fully recognize the data acquisition and management costs and support these activities. In this regard, the regional centers should be required to include the NMHSs of the region of interest in joint and collaborative research and/or service proposals/projects to make them acquire some funds to run the infrastructure at least for the duration of the project. During the implementation phase of the project, the regional research centers should be granted full and open access to the data needed to achieve the objectives of the project as long as it is clearly stipulated in the agreement that the regional research centers do not share that data to a third party without the clearance from the providers, for example, the NMHSs.

6.3. Harmonizing the technical aspects for data discovery and access

For a more effective data exchange in Africa, the data must be discoverable and accessible by humans and/or machines. It should be made available under uniform formats and quality-control standards, with uniform and comprehensive metadata detailing the characteristics of the data along with its history as well as clear requirements for its access. It should be stored in ways that ensure long-term preservation and interoperability. This must minimize technological redundancy by using established national and international repositories. Ideally, the datasets have to be published online in one website protected with a password through a common user interface. They have to be accessible via Internet and downloadable with File Transfer Protocol (FTP). It is understood that the data owners/providers will need more qualified staffs (e.g. in programming, coding and scripting), better IT systems and archiving equipment (e.g. powerful workstations, servers and space disks) and a very good Internet connection. It is thus clear that Africa would benefit a lot in using one common data management system at the continental level and in capitalizing on CLIMSOFT.

At the national level, the observation network operated by any national institution should be regulated and co-coordinated by the local NMHS and their data format and other characteristics should be harmonized with that of the NMHS. Ideally, they could use the

NMHS interface, transmission, storage and management systems for co- quality control and interoperability.

6.4. Strengthening of RCCs and policy coordination

In the face of climate change, human lives and countries economy are at stake. The African countries must respond and tackle the impacts of climate change. This requires a more efficient use of weather and climate information in the different development sectors. To reconcile data owners and CIS producers and providers, the WMO regional climate centers (RCCs) for the specific Regional Economic Commissions (RECs) need to be strengthened to provide the required technical data management and sharing support. RCCs work very closely with NMHSs, and with users at RCOFs forums. At policy level, Climate Research for Development (CR4D) framework could be used for coordination and knowledge exchange at the continental level. CR4D is an Africa initiative that was launched to strengthen links between climate science research and climate information needs in support of development planning in Africa by partnership between African Climate Policy Center (ACPC) of UN Economic Commission for Africa (UNECA), African Ministerial Conference on Meteorology (AMCOMET), World Meteorological Organization (WMO), and Global Framework for Climate Services (GFCS). ACPC/UNECA could work with the different governments in finding funding mechanisms but also the best ways to free the data needed for CIS through legislation.

6.5. Extension of the regional data monitoring meetings

In East Africa at the end of each year, the regional hubs and NMHSs organize a regional data monitoring meeting to appreciate the application of WMO resolution 40 in data sharing in the region. During this meeting, good practices are exchanged, successes and shortcomings are highlighted and ways to alleviate the difficulties proposed. It is worth extending this practice over the whole Africa with a focus in each region and a high level forum at the continental level. In particular, recommendations on practices and areas to improve could be suggested for the inclusion of more data in the sharing process in Africa, especially those needed for the development of tools and products for CIS.

6.6. Creation of a data sharing institution/department

Although there are many operational centers within Africa, none of them specifically and comprehensively address the issue of data sharing. We thus propose the creation of a department (hereafter refereed as institution) dedicated to data sharing within the African continent. This institution can just be a department within a coordination or operational center that has a continental mandate such as ACPC (through CR4D), ACMAD and/or the WMO regional office. Below are the details about how such an institution or department would work.

The governing board

This institution shall be governed by a board consisting of head of African states or relevant ministries. The board will take the leadership for a public support of open access data by taking actions that favors sharing and release of the data and by establishing processes and mechanisms that mandate its effectiveness through legislation. In addition, the board makes key decisions on administration and finance and approves policies, regulations and guidelines that will lead for the establishment and support the functioning of the institution. In the case the board members are from relevant ministries or general directorates, the continuous public support of the head of states will be paramount for the institution to successfully play its role.

The institution/department

The institution develops policies, regulations and guidelines to promote data sharing and enable open access data culture within the continent. It ensures that there is an appropriate suite of regulatory guidance and provide important implementation guidelines as well as measurements and methodologies to assess their impact. Prior to the board meeting, it will prepare key actions to be implemented along with an annual budget and submit it to the board for approval. On a daily basis, it will oversee the data exchange activities based on approved modalities, regulations, guidelines, terms of reference, etc. In this regard, it must be empowered in such a way it can settle and resolve issues raised by a member through filed complaints regarding denied data requests from actors within Africa.

Key actions by the institution

To be able to develop guidelines and regulations for efficient data sharing standards within Africa, a number of actions have to be taken. They include:

- Identify all data owners, CIS tools developers (e.g. research centers), producers and providers within Africa

- Identify data access needs and gaps

- Identify their activities

- Classify these activities into commercial and non-commercial

- Define and create legal means to free the data of all charges for non-profit climate service tools development and information production.

- Define and create legal means to deals with data requests from the private sectors and other commercial activities

The main actors/members

The main actors that will be members of the institution are governments, relevant ministries, NMHSs, universities and national, regional, international and intergovernmental research and service centers as well as all CIS producers and providers (including private sector) within the African continent.

The inclusion of the African governments is paramount for the leadership, public support and approval of any policies, regulations, actions and budget at the board. The relevant ministries will play a key role on identifying and prioritizing data needs and gaps for the different sectors that can include water, energy, agriculture and urban development. The addition of NMHSs will ensure the successful establishment of the institution. In fact, not only they own most of the weather and climate data that will be covered by the policies and regulations, they are also the traditional CIS producers and providers. They can thus play a leading role in the national coordination and provide technical support on data handling, training and advisory. The information generated by NMHSs is often complemented by information from other CIS producers and providers including the private sector which warrant them to be members. Research centers and universities develop, test and refine the tools and methodologies required to generate CIS products and are thus key actors of the arbitration institution.

Funding the institution

The funding agencies must be sensitized towards the importance of data management. It is critical that the institution seeks their commitment and secure funds on a regular basis (i.e. every 5 years ideally) in order to support countries' equipment maintenance and data collection. Ideally, the institution can operate core equipment (e.g. automatic weather stations in strategic locations within each country, satellite receivers and large servers) from which all the data is open and free of any charges to CIS producers and providers. Ways need to be explored in order to secure these funds. One option would be to make mandatory the inclusion of data management in all projects coming to Africa. A certain percentage could be defined, included to the project budget and transferred to the institution.

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