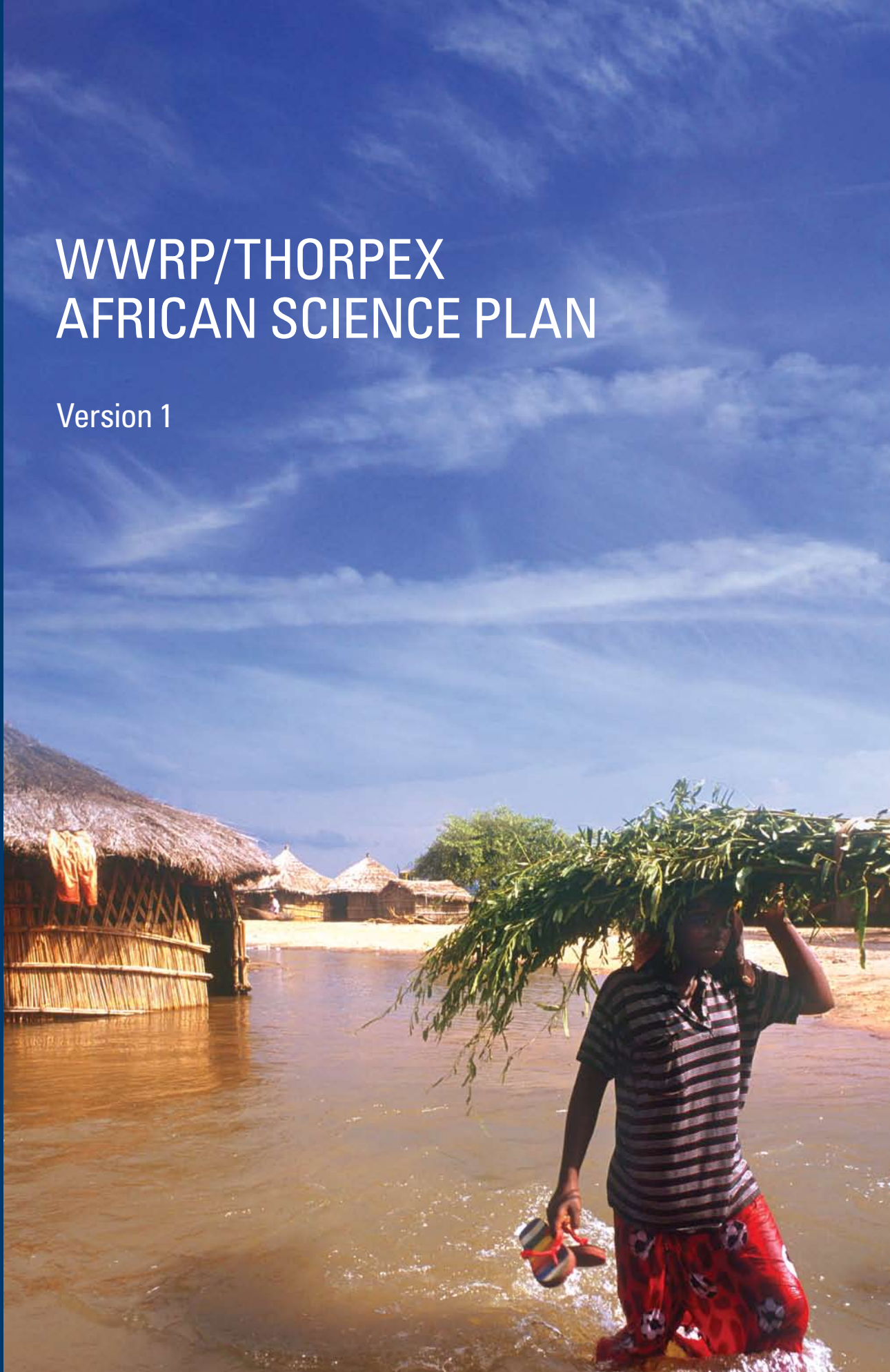


WWRP/THORPEX AFRICAN SCIENCE PLAN

Version 1



World
Meteorological
Organization

Weather • Climate • Water

WMO/TD - No. 1460
WWRP/THORPEX - No. 10



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Chairperson, Publications Board
World Meteorological Organization (WMO)
7 *bis* avenue de la Paix
P.O. Box No. 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 22 730 8403
Fax.: +41 22 730 8040
E-mail: publications@wmo.int

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WORLD METEOROLOGICAL ORGANIZATION



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EXECUTIVE SUMMARY

The Observing system Research and Predictability Experiment (THORPEX) is in response to the challenges of reducing and mitigating impacts of natural disasters and to realize the societal and economical benefits of improved high impact weather forecasts. One major aspect of the international programme THORPEX is the support for development of plans that meet regional needs. This plan is driven by the desire of the African forecasting community to ensure that the THORPEX scientific work is motivated by interests of the user community which has growing and changing needs. THORPEX Africa is being developed with the overall objective of providing and improving one-day to two-week weather forecasts that could meet the needs of African society, the economy and the environment with particular reference to high impact weather events.

Over the past few decades, economic and infrastructure developments have contributed to significantly increased vulnerability to adverse weather particularly in coastal cities and locations in the margins of deserts (Sahara and Kalahari). The economic and societal sensitivity to weather is becoming more significant with increased losses due to adverse weather. This trend is likely to continue with climate change and related increases in frequency or severity of some high impact weather events (IPCC 2001, 2007).

Improving high impact weather forecasts in Africa is a challenge for the following reasons:

- The observing system over the region is very poor and Africa is among the most vulnerable areas of the world in case of high impact weather
- Africa is home to several hundred millions people with significant pressure on resources, food supply and demand especially in desert margins
- Weaknesses in communication infrastructure in most African countries have created a barrier to disseminating forecasts products
- Africa is among the regions where the models and forecasting systems have the highest deficiencies.

Furthermore, processes in Africa interact with mid-latitude and Polar Regions. Thus, improvements of the forecast over Africa may therefore positively impact other regions.

The needs for more skilful, reliable, detailed, local and relevant weather information are placing significant pressure on National Meteorological and Hydrological Services (NMHSs) to help counteract the ever increasing societal sensitivity to weather conditions. Analysis of some users' decision systems shows that information on forecast uncertainty is becoming a basic requirement particularly in cases of high impact events. THORPEX will support the 21st century African forecasting offices to help meet these needs. Predictability and process studies, development and testing of new observing systems, data collection and assimilation, forecast demonstration and applications are activities targeting improvements of high impact weather forecast at 1-14 days timescales.

Very few African NMHSs have access to Limited Area Models and the latest high resolution global model products. These NMHSs issue forecasts up to 36 hours to two days range. However, the majority of NMHSs do not provide medium range guidance or weekly/biweekly outlooks. Ensemble forecasting is being considered as a significant input for production of medium range guidance and weekly/biweekly outlooks for the region.

The WWRP/THORPEX African science plan will have to guide the future involvement of communities and institutions to achieve the following core objectives:

- 1) Increase dynamical and physical knowledge and understanding of high-impact weather systems over Africa and their predictability.
- 2) Identify the needs for an optimal design of observing and telecommunications systems over Africa.

- 3) Encourage and facilitate access to datasets and exchange of ideas and know-how through workshops and newsletters for THORPEX-related forecasting and research activities over Africa.
- 4) Develop and promote socio-economic applications and the use of weather forecast information amongst social, policy and decision-making communities.
- 5) Build the bridge between weather forecasting and climate prediction in order to provide weather forecast information whose timescales range from daily, weekly, bi-weekly to sub-seasonal and even seasonal scales.

The International THORPEX Implementation Plan provides the basis on which the African programme will build coordinated demonstration experiments during the coming years targeting high impact weather events. The WWRP/THORPEX African programme will develop new forecasting approaches that will contribute to reducing the vulnerability of socio-economic sectors to high impact weather events.

The WWRP/THORPEX Africa main area of interest is synoptic to local scale forecasts of the timing, position and severity of high impact weather events in Africa and development of skilful forecasting techniques or procedures for:

- Heavy precipitation, monsoon rain onset and withdrawal, wet and dry spells, heat and cold waves, strong winds and dust/sand storms at short to medium range
- Deterministic or probabilistic outlooks with uncertainty information are major goals of the WWRP/THORPEX African programme.

The African plan is structured in conformity with the International THORPEX plan to address major issues related to three sub-programmes:

- Predictability and Dynamical Processes (PDP)
- Observing Systems, Data Assimilation and Observing Strategies (OS/DAOS)
- Societal and Economic Research and Applications (SERA).

The dynamical processes studies will tackle the following scientific questions:

- What is the available knowledge and understanding of the dynamical and physical processes of high impact weather systems in Africa?
- How can we improve our understanding of dynamical and physical processes and their associated phenomena (such as convective systems, easterly waves, cyclones, sand and dust storms, extratropical disturbances...)?
- How can we contribute to better representation of African weather systems in numerical models?

Particularly, predictability research should bring answers to the following scientific questions:

- What is the skill of the prediction of high-impact weather systems at different time scales?
- How can we improve and extend the limit of predictability of high impact weather systems in Africa?
- How can we access, use and evaluate EPS in Africa?
- To what extent can forecast error statistics and other model output post processing techniques be utilized to improve predictions in Africa?

Scientific questions on observing systems are:

- How can we consolidate and maintain the existing observing systems in Africa?
- What manageable telecommunication systems can enhance the exchange of data and information between African NMHSs, regional and global centres?
- What combination of atmospheric, oceanic and land variables, and at what temporal and spatial scale, and with what tolerable observational error level, could lead to high quality analyses and forecasts over Africa and the globe?
- Which level of increase in observed variables or improvements in observation quality or resolution will significantly lead to better analysis fields?
- How can we make observing systems more adaptive to the changing needs of the user communities and/or to the requirements of the forecasting process?
- With current and future investment in remote sensing systems, what is the most cost effective way to mix current and planned platforms to provide the optimal African contribution to the global observing and telecommunication systems?

Data assimilation and observing strategies questions:

- Given the limitation in the present conventional African observing network and current constraints (funds, technology, high volume of satellite data), how can we support and contribute to procedures that can better assimilate remote sensing and other aircraft observations?
- How can new observations affect or contribute to better monitoring and forecasting of high impact weather?
- What are the suitable data assimilation systems to have a good representation of atmospheric circulation over Africa and how can we contribute to and support the improvement of those data assimilation schemes?

The burning questions related to Societal and Economic Applications Research in Africa are:

- How can we better disseminate the forecast information in order to reach the end-users?
- How do users interpret and apply (or not) forecast information?
- How do we integrate all stakeholders (NGOs, social sciences, etc.) through interactions to produce suitable information tailored to the user needs?
- How can environmental, societal and economic benefits be quantified and evaluated by the end-user?
- What is the most cost effective combination of observing systems, data assimilation, forecast and application procedures (Early Warning System) to improve high impact weather forecasts from user perspective?
- How can ensemble techniques be efficiently used to estimate forecast uncertainties?
- What are the best ways to communicate forecast uncertainties?
- How do we build and maintain an information system on African high impact weather?

A separate Implementation Plan provides more detailed information on the initial activities that will address the above questions.

A participatory approach through two-way consultations involving forecasting and user communities will facilitate identification of problems and obstacles, pathways leading to solutions and the partnerships or collaborations needed to optimally operate. More importantly, given the fact that many African countries are developing nations with very limited modelling and trained human resources, strategic international collaborations with world modelling centres and funding agencies interested in African weather systems are critical for implementation of WWRP/THORPEX Africa. For example, AMMA, MEDEX, Southern Hemisphere THORPEX, ClimDev Africa have initiated collaboration between African Centres and global weather centres. These collaborations are expected to be expanded over all African sub-regions in the framework of WWRP/THORPEX Africa. AMMA has also initiated some preliminary experiments (AMMA-SOP,

Forecast Demonstrations, data assimilation and sensitivity studies). Additional effort in Africa will be pursued to identify a comprehensive set of high impact weather forecast problems and solutions. To maximize benefits, THORPEX Africa will closely collaborate with international weather centres and interface with the climate community for better monitoring and development of a seamless suite of weather and climate forecasts. Joint WCRP/CLIVAR Africa –THORPEX Africa initiatives will be promoted. On the other hand, THORPEX Africa will also benefit from other programmes. To effectively reach this goal, an education and sensitization programme will be carried out to facilitate incorporation of the results from the new forecasting process into a wide range of user decision systems in Africa.

The overall success of THORPEX Africa will be measured by environmental, societal and economic benefits from the new forecasting process. Evidence that these benefits significantly exceed the new forecasting approach development, implementation and maintenance costs will constitute some of the main performance measures. An assessment of the comparative value of different module improvements on the entire societal and economic value of the forecasts will guide decisions leading to new science directions and rational attribution of resources to ensure that the continent builds an optimal and cost effective forecasting system and associated operational infrastructure.

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1. INTRODUCTION

Weather forecasting and applications have become important worldwide issues due to growing sensitivity of human activities to anomalous weather and climate conditions. Tropical cyclone related floods reduced Mozambique's annual growth rate from 8% to 2.1% in 2000 (World Bank, 2001). Droughts in East Africa reduced the hydroelectric potential of Kenya leading to more than a US\$ 50 million emergency loan (World Bank, 2000). This situation has prompted changes in the orientation of African National Meteorological and Hydrological Services (NMHSs). Their activities are moving from mainly making observations to contributing to sustainable development with meteorological assistance to sensitive economic activities (Afiesimama, 2007). However, the performance and utility of weather forecasts in Africa are usually relatively low compared to many other parts of the world.

Continuous monitoring and correction of biases in forecast models over Africa is not yet a regular exercise. In some instances, forecasts may not reach the user community on time or not be well tailored to user needs due to limited capacity in education or communication. Limited human, institutional and infrastructural capacities in Africa for production, communication and applications of weather information are other impediments leading to low utility of weather information. The WWRP/THORPEX Africa Programme is designed to tackle these challenges and support African NMHSs to become major service providers for sustainable development.

This Science Plan proposes to:

- Develop better forecasting and tailored products for user needs
- Test and develop training on new forecast models interpretation techniques
- Test and use more cost effective observing and telecommunication systems
- Improve understanding of African high impact weather systems and their predictability
- Test methodologies to estimate and communicate forecast uncertainties
- Monitor performance of forecast model products over Africa.

This plan also paves the way for research and development on the degree of sensitivity of African societies and economies to weather events. Social science research is expected to define the changes needed in the role of the forecasting community to better support the African economy and society.

During the 20th century, many African meteorological services have played the major role of data providers with very limited interactions with the users and businesses. With the challenges ahead related to new and specific demands, substantial interactions with the users will be critical to detect and handle obstacles and effectively contribute to Millennium Development Goals.

The result will be that the 21st century forecast provider in Africa should be able to:

- Identify activities and sectors affected by high impact weather events
- Be familiar with practices, problems and the decision systems of users
- Anticipate and identify the needs of users
- Adjust products and information to make them more useful for every targeted user
- Develop efficient communication and education support tools to facilitate regular exchanges with the customer.

1.1 Background

THE Observing system Research and Predictability EXperiment (THORPEX) is in response to the challenges of reducing and mitigating natural disasters and to realise the societal and economic benefits of improved weather forecasts. It was established in May 2003 by the Fourteenth World Meteorological Congress (Resolution 12) as a ten-year international global atmospheric research and development programme under the auspices of the WMO Commission

for Atmospheric Sciences (CAS) through its Science Steering Committee for the World Weather Research Programme (WWRP), and joint CAS/JSC Working Group on Numerical Experimentation (WGNE). THORPEX is a component programme of the WMO World Weather Research Programme (WWRP) which is a component of the Atmospheric Research and Environment Programme.

In pursuance of the broad objectives of the international THORPEX programme, regional THORPEX plans are being developed which are tailored to meet specific regional challenges. The WWRP/THORPEX African plan which is one such plan will strive to achieve the goal and objectives enumerated below.

1.2 Goal and objectives of WWRP/THORPEX African plan

The goal of the WWRP/THORPEX African plan is in conformity with the international THORPEX research programme, whose overall objective is to provide and accelerate the improvements of one-day to two-week weather forecasts that could meet the diverse applications and needs of society, the economy and the environment, with emphasis on high-impact weather forecasts.

The specific objectives are:

- 1) Increase dynamical and physical knowledge and understanding of high-impact weather systems over Africa and their predictability.
- 2) Identify the needs for an optimal design of observing and telecommunications systems over Africa.
- 3) Encourage and facilitate access to datasets and exchange of ideas and know-how through workshops and newsletters for THORPEX-related forecasting and research activities.
- 4) Develop and promote socio-economic applications and the use of weather forecast information amongst social, policy and decision-making communities.
- 5) Build the bridge between weather forecasting and climate prediction in order to provide weather forecast information whose timescales range from daily, weekly, bi-weekly to sub-seasonal and even seasonal scales.

The focus of the WWRP/THORPEX African plan is to establish a continental framework specifically to address weather research and forecast problems whose solutions require international collaboration among academic organizations, operational forecast centres, and users of forecast information.

At the global level, programmes within the World Meteorological Organisation (WMO), the International Council of Science (ICSU) and the UN Education Science and Culture Organization (UNESCO) are interacting together to meet International THORPEX goals.

The WWRP/THORPEX African plan through African regional and subregional meteorological centres will ensure that research activities are well connected with the operational needs of African National Meteorological Services, poverty reduction programmes, emergency preparedness and response plans and sensitive businesses. More specifically, THORPEX African activities will be implicated directly in the Millennium Development Goals (MDGs) to reduce extreme poverty and promote economic growth.

2. MAJOR ISSUES AND SCIENTIFIC QUESTIONS OF THORPEX AFRICA

THORPEX Africa is structured in conformity with the International THORPEX plan to address major issues related to three sub-programmes:

- Predictability and Dynamical Processes (PDP)
- Observing Systems, Data Assimilation and Observing Strategies (OS/DAOS)
- Societal and Economic Research and Applications (SERA).

2.1 Predictability and dynamical processes research in Africa

2.1.1 Rationale

The purpose of the predictability and dynamical processes research in THORPEX is to “advance knowledge of the global-to-regional influences on the evolution and predictability of high impact weather” (Shapiro and Thorpe, 2004).

This THORPEX sub-programme will therefore “address those aspects of the atmosphere, ocean, and land, and numerical forecast systems that contribute to limitations in the predictive skill of high-impact forecasts ranging from one-day to two-weeks” It “will assess the various factors that contribute to current limits of predictability for appropriate forecast attributes, and through this determination, develop and demonstrate new dynamical interpretations, and observing-systems and forecasting strategies that will extend these limits” (Shapiro and Thorpe, 2004).

However, high-impact weather systems need to be addressed in their environment, whose variability often relies on intra-seasonal to inter-annual timescales phenomena (e.g., Madden Julian Oscillation, El Niño Southern Oscillation...) and on specific teleconnections (e.g., Asian Monsoon, extra-tropical Rossby waves, extra-tropical dry air intrusions). Improvements in the knowledge of dynamical and physical processes, at intra-seasonal to inter-annual timescales, will thus contribute to refine and extend atmospheric predictability, in particular from short to medium and extended ranges. Moreover, research under THORPEX requires to be tackled from socio-economic applications and users' needs. Therefore the African THORPEX research will explore the influence of inter-annual and sub-seasonal climate variability on forecast skill, highlighting collaborations with climate communities and contributing to the establishment of a relevant link between weather forecasting and climate prediction. The THORPEX objectives are to work on high-impact weather systems and forecasts rather than climate issues, but all relevant timescales for improving forecasting skills and social-economic applications will be considered.

2.1.2 Objectives

Main objective

The main objective of Dynamical Processes and Predictability THORPEX research sub-programme is to improve knowledge and understanding of dynamical and physical processes and their effects on predictive skill of African high-impact weather systems.

Specific objectives

- 1) Identify and/or improve knowledge of large-scale phenomena and teleconnections affecting African high-impact weather systems on intra-seasonal to inter-annual time scales and quantify their effect on predictability of African atmospheric features (e.g. MJO, ENSO, Asian Monsoon, NAO, AAO, QBO, etc).
- 2) Determine what limits predictability at daily, subseasonal, and seasonal timescales.
- 3) Evaluate the capability of models in Africa and determine their skill.
- 4) Assess the possibility and the potential of using ensemble forecasting products for diverse forecasting activities and applications in Africa. In this scope performance of ensemble prediction system (EPS) products will be evaluated for different space and time scales.

The potential development of EPS with African NWP models will also be explored as well as the use of TIGGE forecast products (e.g. for specification of boundary conditions for limited area models).

- 5) Document forecasts error statistics and assess the potential of direct model output post processing techniques to improve predictions.

2.1.3 Dynamical and physical processes

2.1.3.1 Overview of regional issues

a) Northern Africa

High-impact weather systems concerning Northern Africa under Predictability and Dynamical Processes sub-programme include:

- Summertime and wintertime cold fronts and their associated synoptic-scale waves in the extra-tropical westerlies
- Cyclones producing high-impact weather systems such as floods and strong winds
- Sand and dust storms, having high impacts on sectors such as health, agriculture, aviation and transport, and dispatching a large amount of mineral aerosols into the atmosphere, which widely influences its dynamics and physics.

Since the Mediterranean basin largely influences meteorological issues over Northern Africa, and vice-versa, the THORPEX African regional programme will have to coordinate its research and development activities with other programmes taking place over or including this region, in order to be as cost-effective as possible and to benefit from mutual activities in some fields. In particular, the THORPEX African regional programme and other programmes such as MEDEX or THORPEX European regional programme will define ways to collaborate and complement each other's effort. MEDEX (<http://medex.inm.uib.es/>) aims at improving the knowledge of meteorological phenomena relevant to Northern Africa such as cyclones – in the widest sense - that produce high-impact weather systems, to provide better forecast products and to mitigate the negative social and economic effects of such events. MEDEX will explore the connection between cyclones and high-impact weather in the Mediterranean and investigate the physical role (in the formation and evolution of cyclones that produce high-impact weather in the Mediterranean) and model representation/assimilation of orography, surface fluxes of latent and sensible heat, latent heat release, upper level potential vorticity and low level jets.

b) West and Central Africa

High impact weather events over Central Africa are associated with heavy rain and thunderstorms, which may be accompanied by damaging strong winds and floods. Droughts are rare over this part of Africa. The most important feature associated with the evolution and predictability of high impact weather over Central Africa is the Inter-Tropical Convergence Zone (ITCZ).

A monsoon regime characterizes West Africa: the West African Monsoon (WAM hereafter) It is one of those complex subjects that combine and involve many issues: mesoscale convective systems, aerosols, surface-atmosphere interactions, easterly waves, tropical cyclones, etc. The WAM is also one of the phenomena that have the highest socio-economic impacts, in particular on food and water resources and health in West Africa through early/late monsoon onset and withdrawal, dry/wet spells, floods, and dust events.

Although THORPEX research focuses on improving predictability on 1 day to 2 weeks, forecasting activities related to WAM need to be addressed in a wider context, since a strong modulation of weather occurs due to environment variability on the inter-annual, seasonal and sub-seasonal time scales. Therefore the WAM system will be tackled from a more general viewpoint. Improvements of the WAM understanding at timescales going beyond 15 days will directly benefit forecast products and thus societies and economies. In this framework, AMMA (<http://www.amma->

international.org) will be a key partner to advance knowledge of the evolution and predictability of such a high-impact weather system.

c) Eastern Africa

High-impact weather events over the region, include flash floods, hail storms, frost, fogs and wind gusts. Torrential rainfall and floods due to tropical cyclones and storms, which depend on SSTs, severely affect parts of Eastern Africa, especially the countries to the South (like Madagascar, Mauritius and Comoros). Depending on their time of occurrence, cyclones are also known to disrupt the onset or cessation of the seasonal rainfall over other parts of Eastern Africa, thereby interfering with socio-economic activities, including real-time farm operations such as planting activities, spraying of pesticides, application of fertilizers and harvest. Hail storms, frost, fogs, wind gusts and some floods are a consequence of the interaction of large-scale systems and local factors (e.g., Mukabana, 1992; Asnani, 1993). Slope triggering of convection, mechanical turbulence and thermal initiation of convection are examples of local forcing. Elevated heating corresponds to a thermally direct circulation and convergence at the top of the mountain (Hastenrath 1991). Highlands may also create relatively dry conditions, thus reducing the rainfall of the surrounding area due to the blocking of air streams creating a leeward rain shadow.

The influence of the lakes over the region, together with the nearby topography (Figure 1), enhances convection associated with thunderstorms in the region, their interaction with large-scale systems and the processes through which these local features modify the weather are not well understood. These pose unique numerical modelling challenges that can be addressed within the African THORPEX programme.

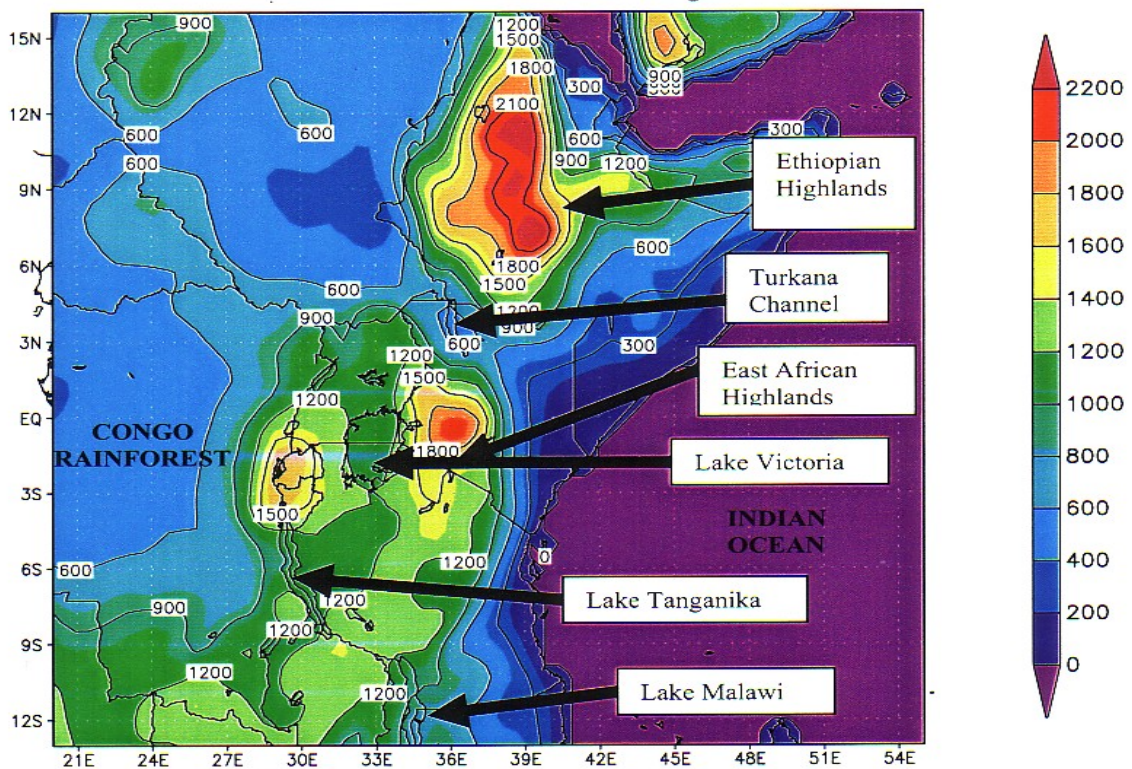


Figure 1. Topographic map depicting physical features of the Greater Horn of Africa. Elevation is in meters (Bowden, 2004)

d) Southern Africa

In Southern Africa, weather phenomena having a high geographically dependent socio-economic impact include:

- Tropical cyclones in the southwest Indian Ocean causing floods in South Africa and Mozambique
- Rapid cyclogenesis near the South African coast, causing gale-force winds and heavy sea swells
- Cut-off lows causing widespread rain and flooding during summer and extreme cold and snow during winter
- Berg winds causing hot and dry conditions conducive to the spread of wildfires
- Severe thunderstorms creating hail, wind gusts, tornadoes
- Semi-stationary mid-tropospheric anticyclone leading to heat wave conditions during summer
- Frost
- Fog at busy airports and along national roads.

Southern Africa is part of the Southern Hemisphere THORPEX. The African THORPEX regional predictability and dynamical processes sub-programme will have to coordinate its activities with the Southern Hemisphere programme to combine efforts and avoid redundancy.

2.1.3.2 Major scientific issues

a) Tropical weather systems

Mesoscale Convective Systems (MCSs)

Mesoscale Convective Systems (MCSs) are often characterized by a large scale organisation, reaching several hundreds kilometres, a lifetime of several hours to a few days, and a propagation velocity of about 15 m/s (Figure 2). MCSs are often organised along lines with a convective part with many convective elements ahead and a large stratiform part behind. A gust front and a high temperature decrease generally get ahead of the system.

The lifecycle of squall lines (*i.e.* MCS organized along a line) may be complex with several phases of decay and intensification. However four steps may be identified: *initiation*, *intensification*, *maturity* and *dissipation*. Initiation (or *triggering*) of convective systems is a highly complicated phenomenon, which may correspond to and involve many different processes.

Some experiments, such as, GATE (*e.g.* Houze and Betts, 1981) and COPT81 (*e.g.* Chong *et al*, 1987) facilitated improvements of our knowledge of the dynamics and thermodynamics of these MCSs. However their interactions with other dynamical structures, local and large scale organization of convection, and land-surface processes need to be further investigated. In particular, there is a need to determine the factors that influence the triggering, the propagation and intensification of these systems.

These systems, because they are the major source of rain in many parts of Africa have high societal and economic impacts. For example, over the Sahel region, which is known to be a drought prone area, MCSs bring more than 70 % of rain (Laurent *et al*, 1998; D'Amato and Lebel, 1998).

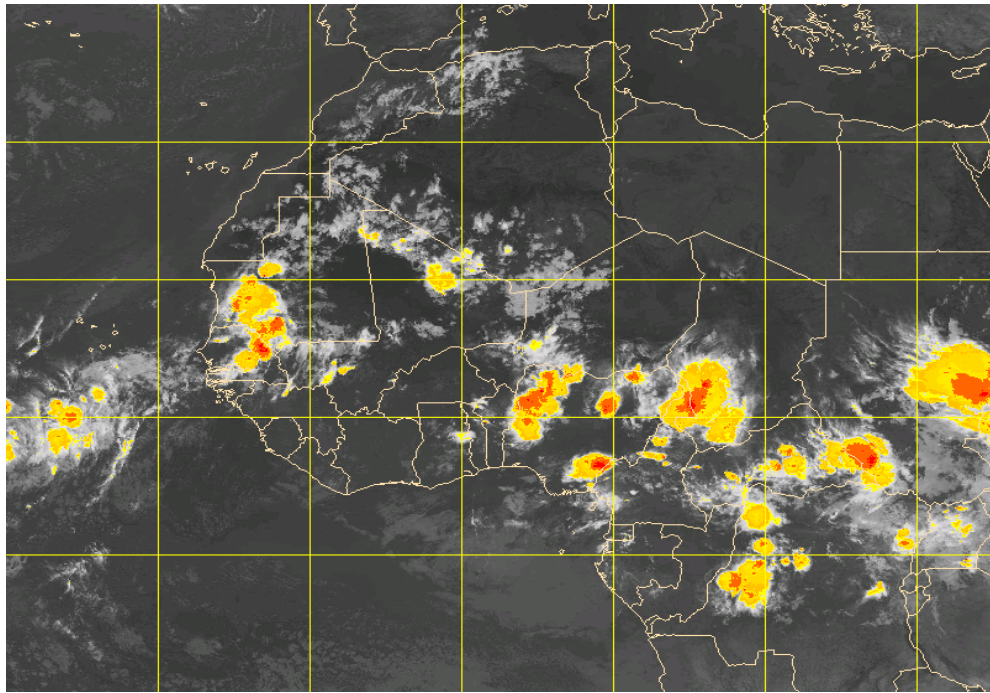


Figure 2. Mesoscale Convective Systems developing over West and Central Africa. Meteosat IR picture on July 27th, 2006 at 23h30 GMT

Easterly waves

AEWs interact with monsoon flow and MCSs. Therefore, the understanding of their dynamics and interaction with the environment is of great interest to improve forecasting of MCSs. They have been the subjects of many observational and modelling studies. Burpee (1972; 1974) and Reed (1977), based on GATE¹ data indicated that AEWs propagate westward in the West African mid-troposphere between June and September, with a wavelength of 3000- 4000 km, a period of 3-4-days , and a propagation velocity of about 8 m/s. It was also demonstrated that the development of such waves was linked to barotropic and baroclinic instabilities of AEJ in the mid-troposphere. The following studies (Thorncroft and Hoskins, 1994; Diedhiou et al., 1999) contributed to improving our understanding of the origin and the structure of AEWs as well as their interactions with convective activity. However, AEWs interactions with convection and other key elements of the surface and large-scale environment of WAM (e.g., TEJ, monsoon layer winds) still need further studies.

Tropical cyclones

Tropical cyclones represent a major natural meteorological disaster affecting tropical regions and producing extreme socio-economic impacts, especially loss of life and damage to infrastructure that isolate impoverished and remote communities. Figure 3 shows that two African regions are concerned with tropical cyclones. The South Indian ocean coast is often prone to encounter such disasters, whereas the West African coast is one of the locations for Atlantic tropical cyclones genesis.

¹ GARP (Global Atmospheric Research Programme) Atlantic Tropical Experiment

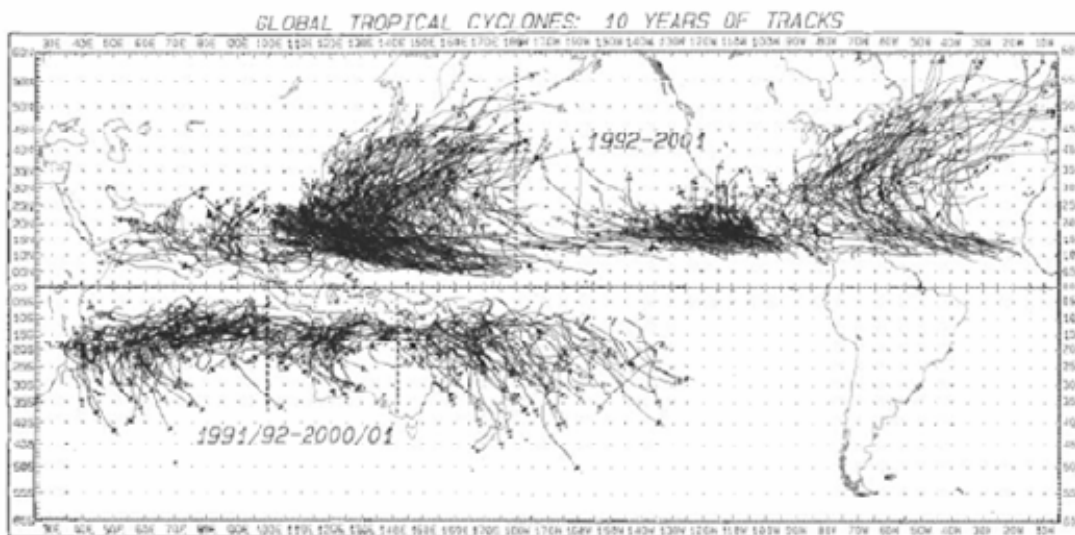


Figure 3. Tropical Cyclones from 1991 to 2000

Over the Atlantic Ocean it is known that many tropical cyclones originate from African weather systems such as easterly waves and mature squall lines coming from West Africa. A good understanding of the processes that organize these systems and modulate their intensity when they enter the ocean environment is lacking. Recent research has suggested that the Saharan Air Layer (SAL) may also significantly weaken pre-existing tropical cyclones (Dunion and Velden, 2004). The combination of the SAL's synoptic-scale dry, dusty air and associated vertical wind shear below 700hPa also tends to inhibit deep convection, essential for tropical cyclone formation. The relative importance of these processes in limiting tropical cyclone development is however not well understood.

Over the Indian Ocean tropical cyclones can have very devastating effects on Eastern and Southern parts of the African continent. Eline² was one of the most devastating for Africa. It affected the African Indian ocean coast in February 2000, flooding large parts of Madagascar, Mozambique, northern South Africa, Zimbabwe and Botswana (Figure 4).

The key issue is how to extend the predictability of these cyclones out to a week or longer, particularly tropical cyclone severity and landfall locations.

Internationally, tropical cyclones are already an area for research under the World Weather Research Programme's (WWRP) Tropical Meteorology Research Programme (TMRP). Therefore, the THORPEX African regional programme will coordinate with the WWRP/TMRP and focus on extending the lead time for tropical cyclone forecasting and improving related early warning in Africa.

² See <http://www.weathersa.co.za/Pressroom/2000/2000FebTCEline.jsp>

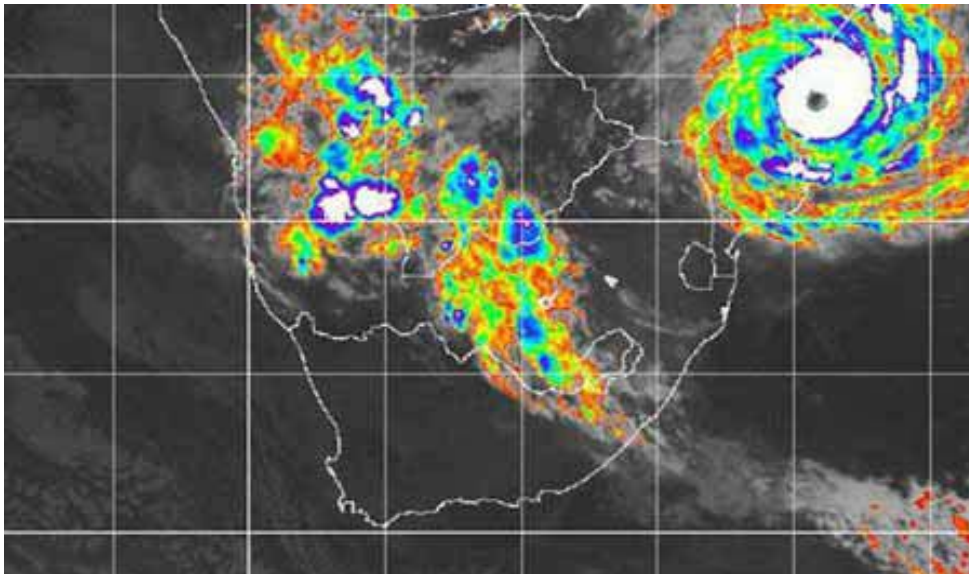


Figure 4. Tropical cyclone Eline provoking flooding in Mozambique and Madagascar

b) Low-latitude extratropical disturbances

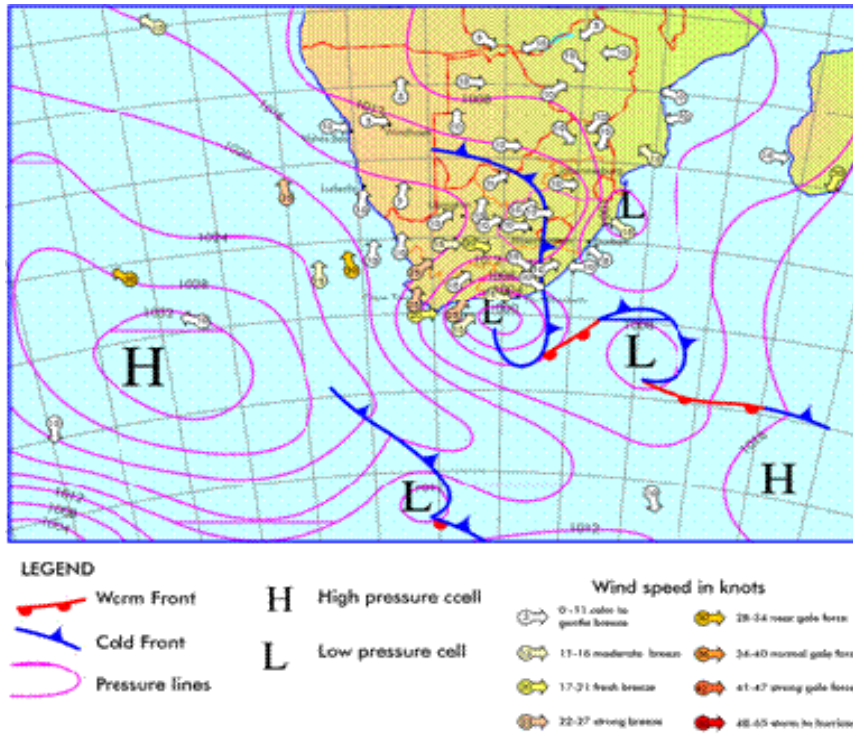
Cut-off lows

Cut-off lows are responsible for the major flooding events and severe windstorms over extra-tropical latitudes, in particular over extreme Northern and Southern Africa. They develop when a cold upper-level low has become displaced out of the basic westerly flow of the jet stream and usually lies to the south of the jet, creating a slow moving area of unstable weather (it is the opposite in the Southern Hemisphere). It is associated with a mid-tropospheric trough deepened through cold-air advection and then cut off through warm-air advection. Such an atmospheric circulation, which becomes displaced out of the predominant flow, often results in heavy rainfall (due to moist air advection from tropical Africa, ocean or the Mediterranean Sea), gale-force winds and other severe weather. Key factors include:

- 1) Convective instability.
- 2) Sustained feeding current of warm and wet air from low levels, able to replace the large amount continuously removed by heavy rain.
- 3) Forced ascent of air, to reach the saturation level, destabilizing the air column and releasing the potential or latent convective instability.

Orography and the specific characteristics of the location often tend to strengthen some features and the impacts of the cut-off lows, but also to make the forecast more difficult. For instance, the high topography of South Africa, with an accompanying steep escarpment adjacent to the east coast, and the warm, southward flowing Agulhas Current, play an important role in the synoptic development of these systems.

On March 2003, South Africa experienced such an atmospheric configuration (Figure 5), whose consequences are likely to remain in Western Cape Province weather record books. During March 18th and 19th, an unusually well-developed cut-off low pressure system was trapped over the Northern Karoo areas, producing heavy rainfall. Some areas of the south coast were also under rain. This rainfall was seen as breaking an extended period of drought. Another cut-off low system developed from Saturday 22nd to Tuesday 25th, this time moving very slowly over the south coast and its adjacent interior. The system was associated with a strong uplift of moist warm air originating in tropical Africa. Behind the low, strong cooling due to influx of cold air originating in areas far south of the country was happening. Due to the severe weather and floods, there was damage to property, crops and vegetation, loss of live to humans as well as cattle (Figure 6).



24 March 2003 synoptic chart showing surface weather conditions

Figure 5. Synoptic chart showing weather conditions on March 24th, 2002



Figure 6. Major flooding in South Africa in March 2003

Cyclogenesis

Intense cyclones, including shallow orographic depressions can cause extremely violent wind events and heavy rain over Northern and Southern Africa and the extreme southern part of Eastern Africa. On November 9th and 10th, 2001; such a cyclone hit Algeria and Morocco. In just only 18 hours, the amount of rainfall registered at the station of Bouzareah (located on the top of a 400m mountain) reached 261.6 mm, whereas the seasonal normal for November is 96.6 mm. The consequences were devastating, leading to floods in Algeria and Morocco and to around 600 casualties, without counting the about 1500 families without shelter. The damage was estimated at 4 billion US dollars.

The principal ingredients of this high-impact weather system (Figure 7) were:

- A strong convergence of moisture at the surface and in the low levels of the atmosphere
- The presence of a small higher anomaly of potential vorticity and of an anomaly of theta at the surface. This configuration contributes to a strong cyclogenesis from the surface up to the mid levels over the bay of Algiers, leading to enhancement of the convergence of moisture in the low levels
- Strong latent instability and vertical velocity in the low levels
- Orographic forcing, which focused and triggered this instability.

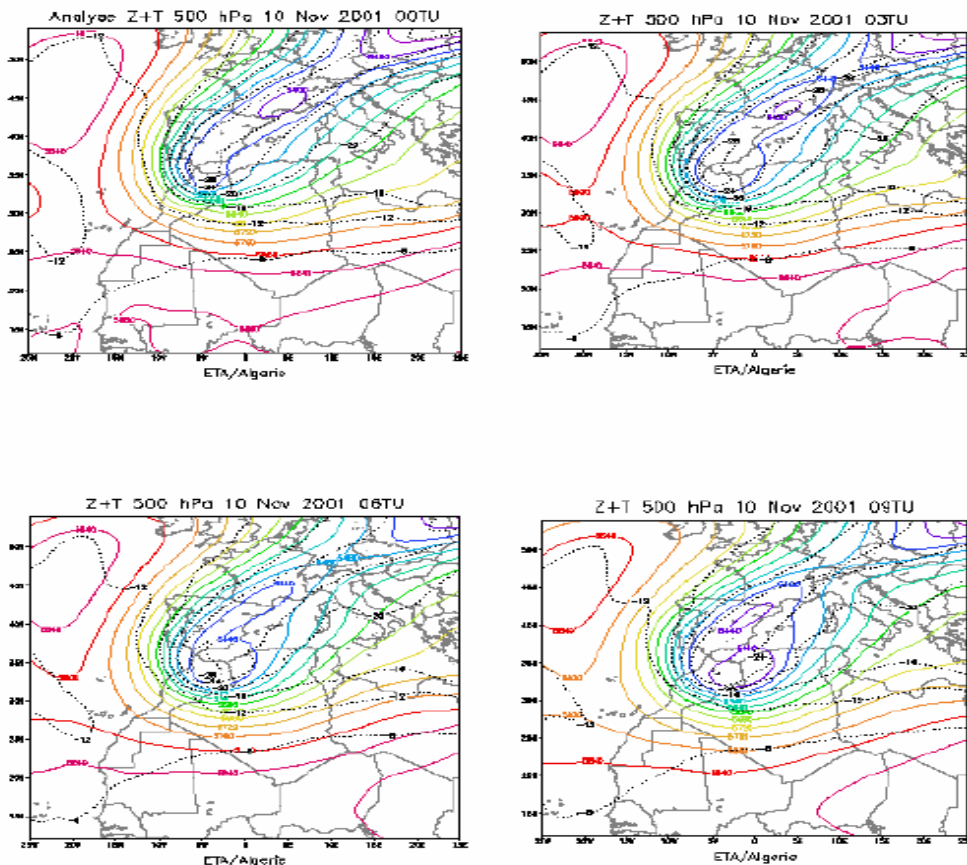


Figure 7. Analysis of Geopotential and temperature at 500hPa, from 11/10 at 00UTC to 11/11/2001 at 09UTC (ETA/Algeria)

Tropical-extratropical interactions

Extratropical disturbances do not only concern the northern and southern fringes of the African continent. They can penetrate to the tropical latitudes at the north-western parts of Africa and can in some rare events cause heavy dry-season rainfall in West Africa. Knippertz and Martin (2005) investigated three cases of extreme precipitation in subtropical and tropical West Africa in order to study the moisture transport, precipitation generation mechanisms and large-scale

dynamics involved. One of the three cases investigated in Knippertz and Martin (2005) affected north-western Senegal and south western Mauritania in the middle of the local dry season in January 2002. The event, classified as the most intense January event on record, produced dramatic socio-economic impacts through widespread flooding, destruction of infrastructure, and large loss of food product. All the cases in their study show strong tropical-extratropical interactions and elongated cloud bands extending from the tropics into the subtropics. These disturbances instigate poleward transports of tropical moisture and upper-level dynamical forcing.

High-impact dry-season rainfall events can be even observed at latitudes farther south in the Soudanian zone. Knippertz and Fink (2007) have provided an observationally based synoptic and dynamical analysis of an abundant rainfall event during the dry season 2003/2004 that affected the countries of Nigeria, Benin, Togo and Ghana. The authors depict the forcing of the rainfalls from the extratropics in the following way:

- (i) "Upper-level clouds and moisture to the east of a weak, quasi-stationary extratropical disturbance enhance the greenhouse effect over the Sahel and the adjacent Sahara, and thereby cause a net-column warming and falling surface pressure.
- (ii) One day before the precipitation event negative pressure tendencies are further enhanced through warm advection and subsidence associated with the penetration of a more intense upper-trough into Algeria.
- (iii) The resulting northward shift and intensification of the weak wintertime heat low allows low-level moist southerlies from the Gulf of Guinea to penetrate into the Sudanian zone.
- (iv) Finally daytime heating of the land surface and convective dynamics initiate heavy rainfalls."

Due to the relation to the usually well predicted large-scale extratropical circulation, extratropical events appear to have a predictability that allows effective warning of the population but this needs to be further demonstrated. The Africa THORPEX regional programme will investigate further this aspect with more case studies.

c) Sand and dust storms

Sand and dust storms are a visible natural process on the African Continent. The vast areas and the distribution and extent of the desert landscape, including the Sahara Desert, indicate that this region was the source of material for sand and dust storms in historical time. Such wind-sand-dust disasters happen frequently on the African Continent, powerful wind and dry convection over deserts being the dynamic force causing sand and dust storms.

At the southern fringe of the Sahara Desert, a special dry and hot wind, locally termed *Harmatta*, brings impacts to Mali and other countries in the Sahelian region. These north-easterly or easterly winds normally occur in the winter season under a high atmospheric pressure system. When the wind force of *Harmattan* is beyond a well-defined threshold value, sand and dust particles will be blown away from the land surface and transported for several hundreds of kilometres to the Atlantic Ocean (Figure 8). Sand and dust storms have even stopped air flights crossing the affected region.

At the northern fringe of the Sahara Desert, strong windy weather often occurs in the winter and spring seasons. This wind is locally termed *Hamson* or *Wind Hilleck* in Algeria. When a low-pressure system occurs in the north of the Sahara Desert or above the Mediterranean, the turbulence takes place from the west to the east. Strong winds will transport hot sand and dust particles from the Sahara Desert to the Mediterranean coasts and the delta of the Nile. The *Hamson* can blow for 50 days without stopping and reduce visibility to a few metres.

In recent decades, the study of atmospheric aerosols has generated great interest from the scientific and societal point of view. The adverse effects on human health are quite evident, causing for example asthma and lung problems. Also, the dust episodes are often correlated to meningitis outbreaks in Saharo-Sahelian countries. This aspect is investigated further in the Societal and Economic Research and Applications (SERA) sub-programme. Dust and mineral

aerosols also directly impact on agriculture, damaging plant tissues or burying seeds, or on transport and aviation, lowering visibility and introducing mechanical efforts on aircrafts.

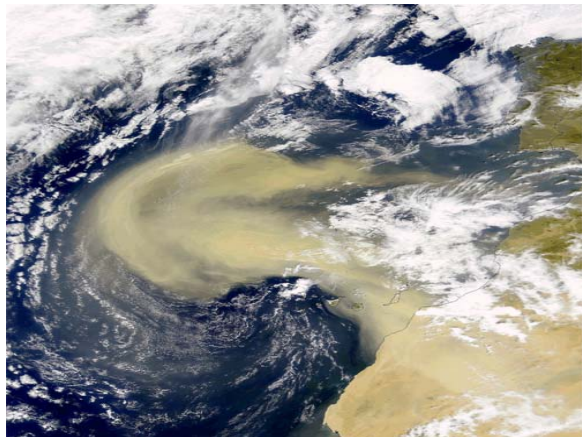
Dust also affects clouds through ice nucleation processes. As a consequence, such aerosols influence convection processes and the formation and growth of mesoscale convective systems, and thus have a high socio-economic impact through modification of rainfall.

However an aerosol/dust observation network is lacking over Africa. Even if today aerosol and chemical variables are considered as essential climate parameters, the next generation of NWP models is already thinking of including them: the future forecast community will regard these essential climate variables as also essential weather variables.

One major problem in monitoring, modelling and predicting the dust cycle is the emission strength, which depends on soil properties and low-level wind speed. Strong winds that can mobilize dust can be related to synoptic-scale extratropical systems, organized convection and dry convective PBL mixing (dust devils, dry convective plumes).



Figure 8. Dust storm in Senegal



Massive sandstorm blows off the northwest African desert (February 26th, 2000)

It appears that particularly the emission related to moist convection needs much more study to get good quantitative estimates and to improve modelling and prediction (see, Knippertz *et al*, 2007).

2.1.3.3 *Scientific questions for dynamical processes studies*

The dynamical processes studies will tackle the following scientific questions:

Question 1: What is the current knowledge and understanding of the dynamical and physical processes for high impact weather systems in Africa?

Question 2: How can we improve our understanding of dynamical and physical processes and their associated phenomena that cause high-impact weather (such as convective systems, easterly and equatorially trapped waves, MJO, cyclones, sand and dust storms, extratropical disturbances...)?

Question 3: How can we contribute towards a better representation of African weather systems in numerical models?

2.1.4 Predictability

The current capability to predict high impact African weather systems in Numerical Weather Prediction (NWP) modelling remains weak, especially beyond the short range. In order to improve this situation, it is necessary to understand and quantify the sources of uncertainty in NWP models.

Uncertainty can be broadly divided into a number of sources. Model uncertainty can derive from inaccurate representation of physical processes, such as cloud microphysics or in the numerical solution of equations such as those for the advection of model quantities. A second source of uncertainty is inaccuracy in the initial conditions used to initialize the forecast. Finally, uncertainty due to the use of a finite resolution model is sometimes categorized as “intrinsic” or residual uncertainty, and is due to a less than perfect knowledge concerning dynamical or thermodynamic perturbations on the subgrid-scale, both in the initial conditions and during the forecast integration.

The ultimate goal of THORPEX for predictability research is to produce forecasts with skill mainly limited by the intrinsic uncertainty. The approach is to address the relationship between model uncertainty, initial condition-uncertainty and the construction of ensemble-prediction systems (Shapiro and Thorpe, 2004)

For Africa, the main goal is to improve the predictability of high-impact weather systems, particularly their timing, intensity and track. The high-impact weather events that are the focus of predictability studies include:

- Heavy rainfall and floods due to severe storms, tropical cyclones and extratropical events
- Dry spells
- Onset of the rainy season
- Dust episodes
- Severe winds (tropical cyclones, Cyclogenesis, dust transport).

To improve the predictability of these African high-impact weather events it is important to identify the relevant factors to take into account in numerical models depending on the scale considered.

2.1.4.1 Relevant factors to consider for predictability studies

a) For short to medium range prediction:

(i) Parameterization of convection

Predictability of rainfall associated with convective systems is generally weak. This weakness is partly a consequence of inadequate parameterization of convective processes in NWP models. Therefore, the use of better convection parameterization schemes may lead to better precipitation forecasts. To date, no consensus has been established concerning the parameterization methodology; using different convective schemes may lead to a totally different representation of convection (e.g. Slingo, 1994). Usually convective schemes initiate the convection process too early, thus generating a false diurnal cycle of convection and precipitation (Guichard et al, 2004). Then the accuracy of simulating the diurnal cycle of convection and precipitation is still poor.

Convective schemes have not only deficiencies in triggering convection on time but also in representing the evolution of propagating convective systems such as Squall Lines, generating an incorrect spatial representation. For these systems, the density current produced by convective downdrafts generate new convective cells, determining the propagation of the convective system. Most current convective schemes don't take into account the internal forcing of convection by density currents (Diongue et al, 2002a), although initial attempts to represent cold pool dynamics in convective schemes are underway (Qian et al 1998, Grandpeix, 2003).

Experience with NWP products in this region has demonstrated better predictability in dynamical fields. An alternative approach to predict rainfall would be the use of statistical methods like neural networks or Bayesian methods using dynamical fields as input.

(ii) Land surface -atmosphere interactions

A good representation of land-atmosphere interactions is crucial for the predictability of African weather precipitating systems. Some studies have pointed out the role of moisture on rainfall over the Sahelian region at short space and time scales (e.g. Taylor and Lebel, 1998; Taylor *et al*, 2005) More broadly, surface heterogeneities, through gradients of momentum, heat, and humidity fluxes, are able to produce mesoscale circulations, which in turn are known to be capable of triggering convection. However the representation of surface forcing such as soil moisture, vegetation structure, topography and albedo is treated in NWP models with a lot of deficiencies in space and time variations.

The problem is more complicated when it comes to taking into account the degradation of land due to human activities. An example is a bushfire which can be a part of the livelihoods of the population in some regions such as sub-Saharan Africa. Actually bushfires create complex islands in a region with highly variable heat and moisture distribution (Intsiful *et al.*, 2005), thus having impact on land-surface-atmosphere interactions.

(iii) Humidity fields

The atmospheric humidity field is a key parameter for a good predictability of the majority of the high-impact weather systems. However it is by far the parameter that is most misrepresented in NWP analysis and forecast systems, leading to errors in triggering and maintaining convection.

Comparing ERA-15 profiles and observed profiles over the Sahel, Diongue *et al*, (2002) found an overestimation of the humidity fields up to 500hPa. Concerning ECMWF analysis, Vesperini (2002) found differences over Africa and South America up to 20 to 30 kg/m² for the total integrated water vapour as estimated from POLDER (POLarization and Directionality of Earth Reflectances) on board the ADEOS satellite in 1997. More recently, during the JET 2000 campaign, ECMWF model analyses and forecasts compared to aircraft observations of the low-level potential temperature and equivalent potential temperature revealed significant departures particularly over the Sahelian and Saharan regions (Thorncroft *et al*, 2003). To overcome the misrepresentation of humidity field in NWP models, measurements of humidity should be first improved. Satellite observation which offers a good spatial coverage and time frequency has difficulties in measuring the humidity over land and cloudy areas. With improvement of data assimilation techniques, more satellite data will be assimilated in NWP models.

(iv) Scale interactions

The interactions between physical processes, mesoscale forcing and large-scale circulation are among the important aspects to consider for improving predictability of African high-impact weather systems. However, NWP models have difficulties in representing simultaneously different phenomena evolving at different time and space scales.

Diongue *et al*. (2002) achieved simulations of squall lines using a high-resolution numerical model, which explicitly resolves convection and includes the two-way interactive grid nesting technique. Such a model configuration enabled the simulation of the lifecycle of the squall line with a high realism and gave many responses about scale interactions between convection and its environment. The use of a hierarchy of models with two-way interactive grid nesting could help to improve our understanding of scale interactions. Similar studies with cloud resolving models could be helpful to improve the understanding of MCSs and the parameterization of convection.

Besides numerical studies, observational experiments at different time and space scales can help to fill the gaps in our understanding of scales interactions between high-impact weather systems and their environment. We expect that experimental and numerical studies in the framework of AMMA will help to improve the understanding of how different scales interact to characterize the WAM and its variability. Similar research over other regions on the African continent and beyond will be promoted.

b) For intra-seasonal to seasonal time scales

The important factors include:

- (i) Large scale convection.
- (ii) Soil moisture.
- (iii) Aerosol forcing.
- (iv) Sea Surface Temperature anomalies.
- (v) MJO, Rossby and Kelvin wave forcing (Mathews, 2004).

In addition to relevant processes representation to improve NWP models, it is necessary to investigate the utility and accuracy of new modelling techniques in Africa such as Ensemble Prediction Systems.

2.1.4.2 Use of probabilistic forecasts

EPS could be helpful to provide the subseasonal weather forecasting guidance. In fact, a large demand for sub-seasonal forecasts, in particular for the date of the beginning of precipitation, monsoon onset/cessation/peak, dry/wet spells, the risk of occurrence, during the season, of extreme weather events such as floods, drought, hail storms, lightning, cyclones, hot/cold spells is arising. The events associated with intraseasonal variability are key elements for decision-making in all climate- and weather-sensitive socio-economic sectors. While medium-range forecasts have become a reality for mid-latitudes, the monitoring of global NWP model performance in tropical regions has suffered a relative lack of emphasis for a variety of reasons, hampering predictability improvements there.

Furthermore many extreme weather situations may be characterized as low probability/high risk: the event is unlikely, but the consequences of occurrence may be catastrophic. Decision-making in this category of events is the most difficult, stretching the capabilities of the tools and the decision-makers. Probabilistic forecasts provide a tool to aid this decision-making process, by characterizing the probability of a particular weather event, and providing more specific information on the array of likely outcomes. To be useful, this information must become integrated into decision support tools.

The development of ensemble prediction is thus an opportunity for Africa. The potential for Ensemble Prediction Systems (EPS) and multi-model ensembles to improve predictions over the African continent is to be further investigated.

2.1.4.3 Use of forecasts error statistics and model output diagnostics

Control of forecast errors in operational models is a regular exercise at advanced forecasting centres to guide forecasters on the interpretation and use of NWP products. Very few comprehensive forecast errors analyses have been carried out over Africa. Analysis of forecast errors (Moorthi, 1997 for the NCEP model; Lau and Yang 1996 for the GLA GCM; Heckley, 1985 and Kamga et al., 2000 for the ECMWF model) is an approach to determine the confidence related to available forecasting systems, document and handle model deficiencies. Forecast error statistics and post-processing of direct model outputs will be promoted in African NMHSs to provide better forecasts guided by a good knowledge of operational model strengths and weaknesses.

2.1.4.4 Scientific questions on predictability

Particularly, Predictability research should bring answers to these scientific questions:

Question 1: What is the skill of the prediction for high-impact weather systems at different time scales?

Question 2: How can we improve and extend the limit of predictability of high impact weather systems in Africa?

Question 3: How can we access, use and evaluate EPS in Africa?

Question 4: To what extent can forecast error statistics and other model output post processing techniques be utilized to improve predictions in Africa?

2.2 Observing system

2.2.1 Rationale

The Observing System in Africa is in a worse state than that of any other Continent (Figure 9) and it was deteriorating until the recent AMMA campaign in W. Africa increased the number of stations, particularly the upper air stations (Figure 10). The President of WMO Regional Association I – Africa (Dr M. S. Mhita), recognised this during the Global Climate Observing System (GCOS) Regional Workshop for Eastern and Southern Africa on Improving Observing Systems for Climate, held in Kenya on October 2001. He identified the declining observation network and communications problems in Africa as the two major challenges for weather and climate monitoring, prediction and early warning in Africa. These realities create key gaps in our understanding of and ability to predict high impact weather events. Monitoring of meteorological parameters is crucial to:

- Monitor and understand the varying weather and in this case high impact weather
- Provide information on which weather related activities can be based
- Initialize and evaluate numerical weather prediction models.

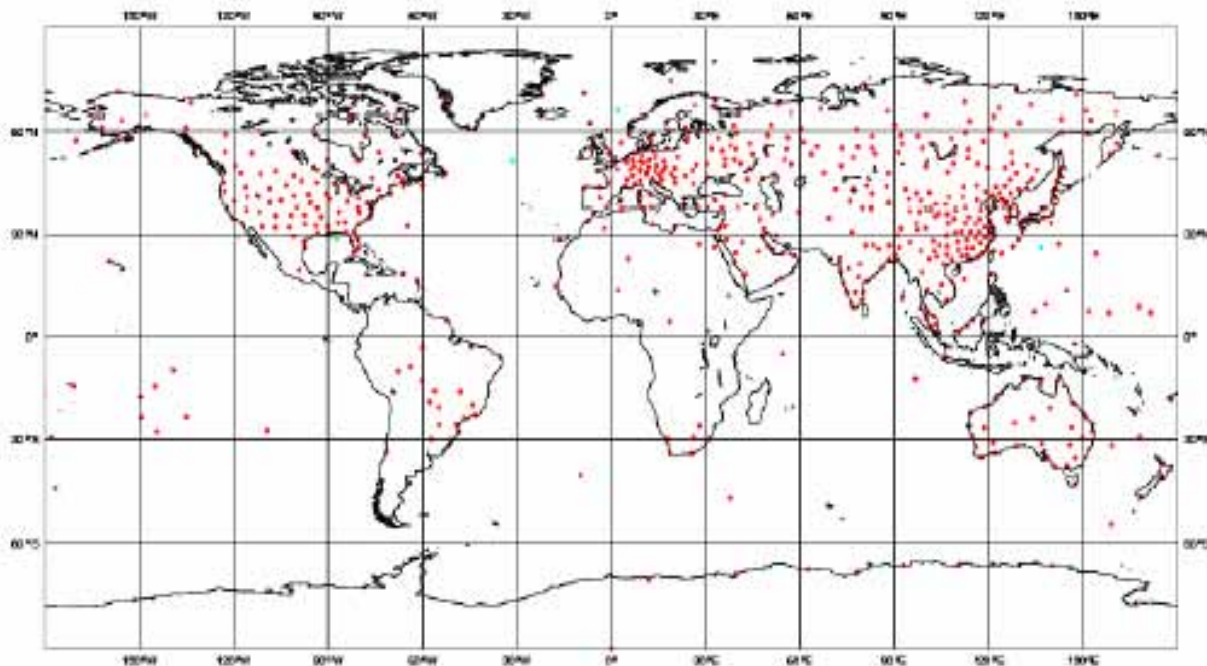


Figure 9. Temp messages received at ECMWF on May 04, 2005 with very limited observations over Africa

reporting of upper air data is even worse but has recently improved in West Africa with modest resources from the AMMA programme.

Many countries 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 weather and user communities in mind. Therefore, the main problems of Observing Systems in Africa can be highlighted as follows:

- Inadequate equipment
- Inadequate staff and planning
- Lack of consumables
- Use of old data formats
- Inappropriate telecommunications systems for exchange of data and information (often obsolete equipment are used)
- Unable to meet up with rapid technological developments
- Lack of awareness by stakeholders (governments, institutions, public and private sectors) of the value of meteorological information in socio-economic development and environmental protection
- Lack of inventory, coordination and access to real time meteorological data and information.

The needed improvements in observing systems fundamentally underpin effective meteorological services in support of agriculture, water resources, health, natural disaster reduction and other sectoral strategies for the reduction of poverty, hunger, disease and environmental degradation. Basic observations and data exchange are essential pre-requisites for all social-economic applications and thus need to be examined immediately to address critical deficiencies. It is of paramount importance to notice that these issues not only affect the African meteorological services but also the entire globe with regard to safety, climate and weather monitoring, disaster reduction, poverty alleviation and economic growth. The interdependence of global weather and climate patterns requires international efforts in monitoring.

The Observing System THORPEX sub-programme aims at “exploring the potential for new observing technologies to provide observations that improve the skill of high-impact weather forecasts” (Shapiro and Thorpe, 2004). This objective must obviously be adapted to the specific situation of Africa. Observing systems research under THORPEX must be carried out in the context that each of the meteorological services of the African countries has an ongoing need to rehabilitate and maintain its observing system to deliver its basic forecasting and climate services as required by their government.

Some programmes are already exploring the improvements of observation and telecommunication systems in Africa. The African THORPEX Regional Committee will have to base its activities on them, in order to articulate efforts and resources:

- In 1996, on the initiative of the African NMHSs, the PUMA (Preparation for the Use of Meteosat Second Generation in Africa) Task Team was created, to ensure that African NMHSs and regional and sub-regional centres maintain their primary access to global weather information following the change of satellites. The PUMA Task Team developed a strategy for the transition between generations of satellites for the African user community, and to support the resource mobilization efforts necessary to fund the replacement of ground receiving and processing equipment. This project is still underway and the African THORPEX Regional Committee will work closely with the PUMA Task Team to enhance availability of meteorological data and products over Africa through the DCP and MDD communication offered by MSG.
- The RETIM-Africa project uses the satellite-based Digital Video Broadcast technology to transmit data files. It is operating via the STELLA/EUTELSAT Atlantic Bird satellite (5°W) and allows African centres such as ACMAD in Niamey (Niger), Harare (Zimbabwe) or

Antananarivo (Madagascar) to receive observational data, NWP model outputs from the global “Arpège” and the “Arpège tropiques” models, a selection of satellite imagery data and various messages. A 1.80-to-2.40-metre dish antenna and a receiving station such as a Synergie PC-based workstation are enough to receive and use the transmitted data. Such material has been installed at ACMAD for forecasting activities during the AMMA Special Observing Period. It can be put into operation within a few hours of installation and only needs basic maintenance and sustainability, and staff training.

- The African world space Radio and Internet (RANET) project initiated by ACMAD will improve the availability of meteorological data and products to user communities, in particular the rural communities, by using digital, wind-up and solar radio.
- The ASECNA-SATCOM project is providing an opportunity for upgrading the regional meteorological telecommunication network in the Western and Central African area, also including Madagascar. The SATCOM facilities should be used for the upgrade of this network not only for ASECNA countries but also for other RA-I members who could benefit from SATCOM services. Interconnection with the other subregions will be enhanced.
- AMMA scientists working with ASECNA and African meteorological services have upgraded the regional soundings network, re-established stations that were down in recent years (e.g., Abidjan), and established several new stations. This effort has also included widespread improvements, to the transmission of data to the Global Telecommunication System (GTS). This has been a major effort involving several hundred people and substantial coordination by AMMA. This experience has involved a deep cooperation among the international community, and many lessons have been learned which could apply in other parts of the continent where the observational network is still fragile.
- Consequent to the ClimDev Africa Strategy and Implementation Programme, a GCOS Regional Action Plan for Africa was consolidated to merge the results of GCOS Regional Workshop for Eastern and Southern Africa on Observing Systems for Climate and those concerning the workshop for Western and Central Africa. The purpose was to support all four Result Areas (i.e. Policy, Climate Risk Management, Climate Services, and Observations, Data Management, and Infrastructure), principally by addressing fundamental climate observation and data management. Since many African GCOS and THORPEX issues are common, close partnership in this area would allow mutual benefits and cost-effectiveness.

Articulation with ongoing programmes such as EUMETNET, AMDAR, Southern Hemisphere THORPEX programme, MEDEX, with WMO’s World Weather Watch (WWW) Programme, with other strategies developed by WMO’s Commission for Basic Systems (CBS) will need to be addressed.

The major THORPEX Observing System research goals for Africa are to encourage the rehabilitation, improve and optimize all the components of the African meteorological integrated basic system. The African monitoring network will have to be developed in a way that enables it to sustain itself at the end of THORPEX decade. This will need the participation of all stakeholders from meteorological services to end-users and will be possible only if they all are aware of the stakes and value of the meteorological information. Demonstrating the quality and value of high impact weather information is therefore quite important.

These research and development activities will take place as an integral part of the Global Earth Observing System of Systems (GEOSS), a major international multidisciplinary programme, aimed at a better assessment and prediction of all processes of the Earth. In addition, Observing System tasks will be carried out jointly with the Data Assimilation and Observing Strategies, and Societal and Economic Applications sub-programmes.

2.2.2 Observing system design

The African THORPEX Programme will perform OSEs and OSSEs to evaluate and refine observing strategies, in particular targeting strategies, to define critical (sensitive) areas for forecasting skill, and to quantify the required accuracy and resolution for the measurement of various quantities. Evaluation of potential new data streams, which may have value for specific weather forecasting regimes (ocean networks for instance), will also be addressed. The optimization of the African observing network will have to be tackled with a cost-and-benefit perspective.

Catching up with rapid technological development is an important failure for most of African countries. Therefore specific skills in this domain should be developed, so that experts could help in improving African observing systems. In particular, the use of technologies (already operational or under extensive test) like AMDAR, rocketsondes, GPS-Observations or future satellite sensors will be evaluated. Satellite-based datasets provide spatially complete coverage and are particularly useful for rainfall monitoring. However this does not obviate the need for conventional observations, as the satellite methods need ground based data for calibration and validation. There remains a pressing need for evaluation of satellite products over Africa.

Understanding the evolution of the state of the oceans is vital to weather prediction on time scales of one to two weeks. Africa's weather is influenced by the Atlantic and Indian oceans, but monitoring of the Indian and Atlantic Oceans in areas proven to be crucial for high impact weather events does not really exist.

Field campaigns

- **Test and evaluate the potential use of remote-sensing and *in-situ* observing systems:** field campaigns will assess impacts on weather forecasts (model outputs and forecaster's expertise) of new observing technologies and determine their potential operational implementation. Field campaigns will also provide a framework for calibration and validation of future remote-sensors (e.g., METOP-IASI) for tropical and subtropical regions.
- **Test and evaluate targeting strategies for new design of African observing system:** Field campaigns will guide the optimization of the African observing system design.

2.2.3 Scientific questions on observing systems

Question 1: How can we consolidate and maintain the existing observing systems in Africa?

Question 2: What manageable telecommunication systems can enhance the exchange of data and information between African NMHSs, regional and global centres?

Question 3: What combination of atmospheric, oceanic and land variables, and at what temporal and spatial scale, and with what tolerable observational error level, could lead to high quality analyses and forecasts over Africa and the globe?

Question 4: Which level of increase in observed variables or improvements in observation quality or resolution will significantly lead to better analysis fields?

Question 5: How can we make observing systems more adaptive to the changing needs of the communities and/or to the requirements of the forecasting process?

Question 6: With current and future investment in remote sensing systems, what is the most cost effective way to mix current and planned platforms to provide the optimal African contribution to the global observing and telecommunication system?

To answer to these questions will require testing of new sensors and observing platforms (e.g. through observing system simulation experiments). More generally, responses to these questions will require collaboration with working groups on data assimilation, forecasts and applications.

2.3 Data assimilation and observing strategies research in Africa

2.3.1 Rationale

There are insufficient observations at any one time to determine the state of the atmosphere. To achieve a detailed and complete picture of the atmosphere, additional information is needed. This is available as knowledge of the behaviour and probable structure of the atmosphere. In this scope, NWP models, which embody knowledge of the flow evolution with time, provide a consistent means of representing the atmosphere. *Data assimilation* is thus the process of leading to an estimate of the state of the atmosphere and ocean at a particular time, which is the most consistent with the observations, as well as a measure of the uncertainty associated with that estimate. This estimate aims at providing 1) initial conditions (i.e. the *analysis*) for a numerical weather forecast, 2) verification data for a prior forecast, and 3) meteorological records for research and climatological purposes. "The estimate is derived from both observations and a first-guess (or *background*) short-range forecast from the previous analysis, along with the statistics of the errors (measures of uncertainty) associated with observations and the background. A significant component of forecast error originates from uncertainty in the initial condition. This uncertainty arises from uncertainties in the observations, the background forecast and approximations in the assimilation scheme.

Recent advances in many aspects of data assimilation and observing systems provide the opportunity for making substantial improvements in forecast skill. These advances include: i) greatly increased volume and quality of atmospheric observations, particularly from satellites; ii) adaptive observational techniques, or targeting; iii) improvements in assimilation algorithms, both in terms of their use of remotely-sensed observations and of their formulation" (Shapiro and Thorpe, 2004). The THORPEX research programme and therefore, its African component will seek to capitalise on these advances.

Some of the data assimilation issues are being pursued within various institutions around the world and therefore are not specific of Africa. However, the importance of these topics to African NWP and to international NWP for Africa deserves to be included within this regional plan. Therefore, some specific issues (aerosol concentration in the lower atmosphere, extreme variability of soil moisture, etc) related to Africa need to be addressed. The research under Data Assimilation and Observing Strategies THORPEX sub-programme will both provide scientific advances within the larger THORPEX programme and meet the aims and objectives of the participating institutions, in particular those of the NMHSs developing NWP models. Besides, the participation of African research and operational communities will allow African NMHSs to contribute to and capitalise on the advances in many aspects of data assimilation, and thus to make substantial improvements on forecast skill.

The AMMA programme overlaps some of these elements: AMMA is providing improved analyses of the West African Monsoon and the tropical Atlantic Ocean. Observations of the atmosphere, land, ocean and aerosol will be used to create reanalyses of the WAM and the tropical Atlantic Ocean to support AMMA science objectives. AMMA observations will also offer an opportunity for coupled reanalysis efforts of the atmosphere, land and ocean. The enhanced observations and data assimilation systems will enable to carry out a host of observing system simulation experiments (OSSEs) that will support research on the utility and efficiency of the current observing system, allowing recommendations to be made for future sustained observing networks.

2.3.2 Potential research foci

This section discusses some issues where an African regional focus within THORPEX can both provide scientific advances within the International THORPEX programme, and meet the objectives of African institutions.

2.3.2.1 Performance metrics

Approaches of data assimilation in regional or mesoscale models are often derived from those of global models. However, techniques related to global models, which are mainly sensitive to large-scale information, can provide confusing or misleading results when applied to high-resolution model. Therefore, the improvement of existing data assimilation performance metrics, and/or the development of new ones, should reflect the potential of any high-impact weather system. Such metrics have also to measure the impact of forecasts on the major users and must be explored in collaboration with the Societal and Economic Research and Applications sub-programme.

2.3.2.2 Assimilation of satellite data

Satellite data have had a significant impact on improving the accuracy of global NWP forecast, especially in the southern hemisphere. Therefore, since the *in-situ* observation network over the African continent and surrounding oceans is weak, satellite data constitutes a valuable potentially major source of observations, which may improve forecast skill, if some shortcomings are overcome (Figure 11). Efforts will be made to collaborate with global modelling centres that ingest these datasets to provide coupling files for African regional modelling centres.

The use of high volume datasets (high spectral and horizontal resolution) was also identified as an important task at the first THORPEX executive board meeting, since high-density data is still discarded from the majority of assimilation systems. One of the limitations is the poor understanding and characterization of the observation errors. The volume of data is also critical and relevant thinning and compression algorithms have to be developed.

Screened			Assimilated		
• Synop:	193616	(0.27%)	• Synop:	39142	(1.57%)
• Aircraft:	254294	(0.36%)	• Aircraft:	158219	(6.35%)
• AMV's:	2186744	(3.06%)	• AMV's:	73574	(2.95%)
• Dribu:	10803	(0.02%)	• Dribu:	3547	(0.14%)
• Temp:	116442	(0.16%)	• Temp:	66405	(2.67%)
• Pilot:	94889	(0.13%)	• Pilot:	49818	(2.00%)
• UpperSat:	68105926	(95.38%)	• UpperSat:	1985939	(79.72%)
• PAOB:	814	(0.00%)	• PAOB:	290	(0.01%)
• Scat:	247320	(0.35%)	• Scat:	114290	(4.59%)
TOTAL:	71.210.848		TOTAL:	2.491.224	

99.06% of screened data come from satellites **87.26% of assimilated data come from satellites**

Figure 11. ECMWF data count on 10th March 2004

The quantification of the observation error covariance requires knowledge of the behaviour of the instrument and the observation operators. Such studies are already undertaken all around the world, but it will be important to characterize this error covariance specifically over Africa, so that data assimilation processes in or for Africa can improve the African weather forecast skill.

Assimilation of more satellite soundings, in particular through active and passive microwave sensors, could bring improvements in the specification of initial conditions for the areas of tropical or subtropical convection where *in-situ* observations are usually lacking. They also can be used for assimilation of cloud and precipitation processes, if the difficulties to represent precipitation and cloud as a function of radiance/reflectivity and to represent physical processes in NWP models are

overcome. Such tasks thus require accurate and sophisticated linear and non-linear forecast models, what can be achieved in limited area models.

2.3.3 Observing strategies

Given the relatively low budgets of many African Meteorological Services, it is a major priority across the continent to rationalize and justify the costs of observations. One approach to this is to evaluate the impact of observations on weather prediction. To this end, for the West African context, THORPEX Africa is collaborating with Working Group 5 in AMMA to coordinate a number of Observing System Experiments (OSEs) with NWP centres around the world (e.g., ECMWF, Météo-France, NCEP and UK Met Office) and institutes in the US (e.g., SUNY Albany, NRL and the University of Miami). The ultimate aim is to make recommendations on what the future observing system should look like in the West African region to support prediction of high impact weather. This international collaboration within the AMMA-THORPEX working group is therefore a model, which could be applied to other parts of the continent, where the logistical and economic context of the observations is similar to that of West Africa.

Targeting strategies could in principle be used to improve the present observing system over Africa and determine the key areas, i.e. the most *sensitive regions*, in which the quality of the analysis has the greatest expected influence on the forecasting skill. However, there is at present no generally accepted scientific basis for producing such sensitivity calculations in the tropics.

Some reasons such as the weak current observing network, financial constraints, etc suggest that targeted observing systems may not be adequate for Africa. This does not however prevent research from undertaking such studies, which may improve observational capacities in Africa and thus African weather forecasting skill. However such strategies must remain modest, meet the objectives of the African institutions, and at the same time contribute to the improvements of data assimilation for the NWP centres around the world. A real involvement of African operational and academic communities is thus required.

Therefore, THORPEX Africa has to emphasize the key weather systems in different regions and to promote research and techniques for producing sensitivity calculations and to identify the associated metrics.

As mentioned above, observing system, data assimilation and observing strategies are strongly interlinked. Data assimilation provides an estimate of the state of atmosphere, land and oceans. This estimate helps to initialize NWP models, develop analysis and reanalysis datasets for forecasts verification, diagnostics and climate studies. Errors in the initial conditions affect the forecast performance particularly at medium to extended range.

Advances in data assimilation are needed to improve analysis or reanalysis datasets.

2.3.4 Scientific questions on data assimilation and observing strategies

Question 1: Given the limitation in the present conventional African observing network and current constraints (funds, technology, high volume of satellite data), how can we support and contribute to procedures that can better assimilate remote sensing and other aircraft observations?

Question 2: How can observations affect or contribute to monitoring and forecasting of high impact weather?

Question 3: What are the suitable data assimilation systems to have a good representation of atmospheric circulation over Africa and how can we contribute and support the improvement of those data assimilation schemes?

2.4 Societal and economic research and applications in Africa

2.4.1 Rationale

Many weather systems or conditions have a high-impact on society, the economy and the natural environment. Applications of NWP products are less developed in Africa and meteorological hazards such as droughts, floods and tropical cyclones often lead to human and economic disasters. The main goals of African high impact weather forecast applications are consequently to define, build and test application tools to mitigate the negative effects of high impact weather on the society, economy and environment. Moreover, improvements in potential benefits related to forecasts of high impact weather events will be promoted in sensitive sectors like disaster management, agriculture, energy production and distribution, health, water resource management, aviation and fishery.

Since the use of numerical forecast products is still limited in Africa, even non-existent in some areas, WWRP/THORPEX Africa will seek to develop projects across Africa (e.g., Demonstration Projects), in key sectors (e.g., emergency management, energy, water, agriculture and health) to show the value of meteorological information to decision-makers for development, and facilitate synergies between the public, non governmental organizations and meteorological services. With the current advances in communication technologies, an African high impact weather information system will be built to share weather and impact data, knowledge, best practices, procedures, standards, success stories, training materials and tools between all stakeholders.

This sub-programme will also promote estimation and communication of high impact weather forecast uncertainties, development of integrated decision tools, verification of forecasts of user friendly variables and assessment of the increase in society's well being related to the use of weather information. Some user friendly variables include the costs of weather events, including loss of life and properties, displaced people, disruption in communication and transportation, etc.... The use of forecast products by decision-makers requires a sequence of actions, which are important to add value to meteorological information for decision-making:

- i) *Design*: The user should be involved in the design of the products to make sure it's tailored to his needs.
- ii) *Content*: the users should be able to find the forecast information related to and relevant for his particular activity.
- iii) *Dissemination*: the users must receive the information on time to make decisions.
- iv) *Communication*: the format of forecast products have to be tailored to the users leading to easier and quicker understanding and interpretation.
- v) *Recognition*: The products should be made in a way that users recognize as high value input in their decisions.
- vi) *Response*: Evidence that users adapt their activity to the given information should be documented. Decision schemes will thus be developed.
- vii) *Evaluation*: The user should be able to evaluate the products based on his own rationale and need, which is a feedback into the forecast system.

This process (i.e. weather forecast *information chain*) implies the development and enhancement of collaboration between meteorological research, economic, policy and social science communities, operational forecast centres and users of weather forecast information to link in the components of the information chain for better efficiency. Economic and social science research is expected to guide interactions between forecasting and user communities by organizing collaborative forecasting and user groups, calibrating utility assessment benchmarks and setting up appropriate communication tools. SERA research will consequently determine the ways in which forecast information could be better used and how it can be improved. For instance, users will be able to better define their information needs and forecasters will explain what is presently feasible and what can be expected in the near future.

Interdisciplinary efforts are more needed with atmospheric scientists working with and using social, environmental and economic scientist methods.

2.4.2 Concerns related to societal and economic research and applications in Africa

The burning questions are:

Question 1: How can we better disseminate the forecast information in order to reach the end-users?

Question 2: How do users interpret and apply (or not) forecast information?

Question 3: How do we integrate all stakeholders (NGOs, Social sciences,) through interaction to produce suitable information tailored to the user needs?

Question 4: How can environmental, societal and economic benefits be quantified and evaluated by the end-user?

Question 5: What is the most cost effective combination of observing system, data assimilation, forecast and application procedures (Early Warning System) to improve high impact weather forecasts from user perspective?

These questions cut across natural, economic and social sciences. These complexities imply more challenges. The new forecasting process will not be a linear sequence of tasks but rather an interactive, interconnected loop of activities and partnerships. The answer to the last question will determine the new cost effective methods and models or schemes easy to implement.

The last key problem is related to estimating and communicating forecasts uncertainties. It is increasingly recognized that presenting forecasts without related uncertainties is a barrier for its use in some decision systems (NRC, 2006). Uncertainty estimation and communication methods are needed to improve the quality and value of high impact weather information. The following questions will be explored:

Question 6: How can ensemble techniques be efficiently used to estimate forecast uncertainties?

Question 7: What are the best ways to communicate forecast uncertainties?

3. BENEFITS OF WEATHER FORECAST INFORMATION FOR AFRICAN SOCIETY

Weather forecasting has been getting more accurate with the development of powerful computers, observing platforms and better understanding of processes and phenomena. Easy Internet access makes weather forecast products from international centres (e.g., ECMWF, Météo-France, UK Met Office, NOAA, NCEP, Bracknell and FSU) accessible instantaneously to many African national meteorological services. One day-to-two weeks weather forecast can have high value for African societies in different sectors such as disaster management, energy, transportation, health, agriculture and hydrology. Improved application of forecast information for energy production and distribution as well as transportation (e.g. the aviation sector) is of high priority because of the significance of commercial airlines contributions to NMHSs budgets and damage or losses related to the increasing frequency of power shortage in Africa. Incorporating weather forecasts into decision tools can increase the efficiency to respond to hazards and disasters (e.g., flooding, disease outbreaks and locust invasions, power shortage, food insecurity).

One of the crucial questions for many African weather information users in a seasonally varying climate is the onset on the rainy season. Once the onset is known, the prediction of dry, wet spells and rain cessation is essential for planning purposes. THORPEX activities at sub-seasonal timescales will contribute to meet these needs.

3.1 Weather forecasts for agriculture

Seasonal climate forecasts are produced by African Climate Outlook Fora (COFs, with SARCOF in Southern Africa, PRESAO in West Africa and GHACOF in East Africa). COFs products are limited in their application because they mostly contain sub-regional scale outlooks valid for a three month period. Seasonal forecasts help the choice of seeds according to their water requirements whereas weather forecast information can contribute to optimally identify the planting period. Crop yield is indeed not only driven by seasonal rainfall total but also by the distribution of the rainfall in the 5-to-10-day timescales within an area of few tens of kilometres. Weather forecasts can thus be very helpful for land preparation, fertilization, seed planting and crop harvesting. In case of late onset well predicted, the planting date can be delayed until the forecast indicates a soil wet enough to meet the water requirements. Farmers can therefore avoid repeated planting operations. During harvesting, a dry period is necessary to facilitate crop conservation and transportation. Crop yield estimation before the end of the season may have weather and climate forecasts as inputs. Weather forecast information also helps to better prepare for or respond to locust invasion. Early identification of potential breeding sites will favour anticipated actions to avoid locust development. Therefore, agriculture requires an integrated forecasting system with weather and climate information as outputs.

Another innovative use of meteorological information in agriculture management is the development of agricultural models coupled with weather models. Joint research initiatives will advance knowledge of 1) the relationships between the weather (and climate) and agriculture or food security, and 2) how errors in the atmospheric models propagate into the application models. A sample research question is what meteorological conditions favour locust invasion over Africa? Or what meteorological conditions facilitate locust development? The important processes that dominate the coupled atmosphere and terrestrial biosphere systems (Lamprey et al., 2005) are different for short timescales (i.e. seconds to hours), intermediate timescales (i.e. days to months) and longer timescales (i.e. seasons, years, and decades). Specific studies on these timescales will be encouraged in partnerships with other programmes.

SERA activities will further explore and promote better adaptation and use of the current forecast information in the agricultural sector. A sustainable agriculture information system will be promoted to facilitate new research activities and reduce losses and damages in Africa.

3.2 Weather forecasts for a better water reservoir management

African countries have dams that provide water and energy. Conflicts have been recorded between communities and countries due to uneven and unfair distribution of sometimes insufficient water and energy reserves. River Basin Authorities have been created to handle conflicts and promote better policies for sustainable management of water resources. The optimal use of weather forecast information in this sector is still to be demonstrated. Water facility initiatives of the European Commission, WMO Hydrological activities and THORPEX African programme will work in the framework of demonstration projects for this sensitive sector. Integrated weather and climate forecast demonstration projects are expected to improve the sustainable management of water and energy production or distribution in Africa. Research activities to couple weather and hydrological models will be promoted between forecasting and water management communities.

3.3 Weather forecasts for better disease control

Malaria epidemics in Africa occur usually during the rainy season. Better preparedness plans are needed to mobilize health specialists, prepare emergency drug supply systems, call for international assistance on time, etc... Weather and climate forecasts have been shown to help anticipate disease outbreak. Vector born diseases need very specific environmental conditions. These conditions can be better identified using rainfall, wind, humidity and temperature data.

Scientists will identify and further refine health user requirements for meteorological information and improve tools to effectively deliver information that meets the demand. The utility of such information for human health needs should be demonstrated, raising awareness of the availability and potential uses of meteorological information for health. Collaboration between THORPEX Africa, Climate and Health programmes under the Health Climate Partnership will

enable efficient use of resources and add value to weather forecasts from a health user perspective.

Many other sectors in Africa are potentially weather sensitive. An information system for different sectors containing high impact weather data and related statistics, forecasts and forecast error statistics, advisories and warnings, past weather events impacts for each sector, success stories from forecast demonstrations and reports on decision systems tests experiments is a major benefit expected from THORPEX Africa. Reduction in losses and damages due to high impact weather, enhanced weather data or information collection, control, archiving and exchange systems, increased number of meteorologically informed decisions and policies, increased number of scientists, forecasters and users exchanging data are additional expected benefits to be derived from the information system.

4. CROSS CUTTING TASKS

Most African countries are developing nations. Capacity building and infrastructure development appear to be key requirements for the sustainability of THORPEX in Africa. To maximize impacts and capitalize on investments, collaborative work between all sub-programmes to end up with recommended configuration for an NWP system that should be realistic, cost effective, adaptive and integrated in decision systems will be encouraged. Crosscutting efforts will involve the following activities.

4.1 Evaluate existing tools and capacity

The first step is to identify strengths and weaknesses of existing tools and capacity in Africa. This assessment covers also existing institutions and the way they work together to produce and use weather information. During this process, skilful products will be identified; better application tools and institutional reforms or arrangements, infrastructure and human resources needed, will be highlighted. The observing, assimilation and forecasting tools will be assessed jointly to ensure cost effectiveness, establish optimal data and infrastructure needs or the best assimilation and forecasting techniques.

4.2 Define and identify high-impact weather forecasts

In order to identify more opportunities for the use of weather forecasts, databases should be developed to assess how the existing forecasting potential could be used in decision-making to reduce the negative effects of past high impact weather events. These databases may contain meteorological parameters, the impacts of events, and the forecast models performance for specific past high impact weather events, how the forecast information might be utilized and how this information could have reduced the recorded impacts, with both quantitative and qualitative data.

On the other hand, research into synoptic features associated with high impact weather will lead to a better knowledge of synoptic meteorology in Africa. Findings on possible synoptic signatures related to mesoscale high impact weather will facilitate forecast operations using available global model products that usually show useful skill at synoptic and large scales. This activity will benefit from advances in information and communication technology for remote data access and processing, MEDEX and Southern Hemisphere THORPEX databases.

4.3 Education and communication

Improvement of awareness on THORPEX African programme objectives and achievements will contribute to capacity building for the public, policy and decision makers. Supporting tools and infrastructure to facilitate communication will be provided to raise the profile of THORPEX in Africa. Summer schools and workshops for forecasters and end-users will help to transfer needs, knowledge and advanced techniques. To encourage high level education and training on high impact weather, the THORPEX African programme will promote more interactions between Universities and operational centres on different research questions mentioned above. THORPEX African programme training and research grants will be considered.

4.4 THORPEX demonstration projects

Demonstrating the value of new techniques and methods to observe, monitor and predict more accurately African high impact weather events is among the most important tasks of THORPEX African programme. Testing of new observing platforms (AMDAR, A-train constellation of satellites, etc) during the Year of Tropical Convection and beyond will help to improve African observing network. Multimodel, ensemble and high resolution deterministic global and limited area models are being used to show improvements in high impact weather forecasts (Westrelin et al. 2006, Jolivet et al. 2005, Knippertz and Martin 2005). THORPEX African forecast demonstration experiments will contribute to building new NWP based training materials for workshops or summer schools, testing real time and near real time monitoring and forecasting products, verifying the forecasts and reporting on the strengths/weaknesses of model products as well as their interpretation and use techniques.

5. COLLABORATION WITH OTHER PROGRAMMES

Promotion of more interactions with university scientists and students on different research topics mentioned above through THORPEX African research grants will contribute to high level education and training. A network of THORPEX African Universities and institutes will be built across Africa in close collaboration with NMHSs and international projects like UNESCO-ICTP and the UCAR Africa initiative.

Given the complex and global nature of weather and the limited resources in Africa, the THORPEX African programme will rely on a strong collaboration with other countries and programmes. The THORPEX African goal is directly linked to African NMHSs missions which are to observe and monitor weather systems, describe and understand their features, predict their track and intensity, advise and inform the public and businesses on their impacts. It is expected that the THORPEX African programme will contribute to helping establish African NMHSs new priorities for the 21st century among these missions. Observations, data assimilation and observing strategies, predictability, forecasting, dynamical processes research and applications are major components of THORPEX corresponding to NMHSs missions mentioned above. African countries are expecting to fully benefit from, and provide contributions to international collaboration on high impact weather forecasting.

5.1 Links with WMO programmes

The THORPEX African programme is the regional component of the international THORPEX (Thorpe and Shapiro, 2004) under the WMO World Weather Research Programme. Since THORPEX is an application oriented research programme aimed at improving operational weather forecasts procedures and related uncertainty estimation and communication in Africa, it is important that the WMO Public Weather Services Programme participates in forecast demonstration activities of THORPEX. The observation component of THORPEX is a contribution to the Global Earth Observation programme with the deployment of AMDAR, drop and drift sonde systems to improve upper air observations and extensive testing and validation of the ever increasing amount of satellite, radar and lidar data in Africa.

The Natural Disaster Prevention and Mitigation Programme will extensively benefit from THORPEX African societal, environmental and economic applications procedures as well as demonstration activities targeting better forecasting of African high impact weather events. Many African high impact events occur on weather and climate timescales (early or late rainfall onset, wet and dry spells, heat and cold waves, flooding due to several days of intermittent moderate rainfall, droughts, etc). Short, medium and extended range weather forecasts will be completed by weekly, monthly and seasonal climate outlooks to better predict these events. The World Climate Programmes and GCOS- CLimDev Africa will work with the THORPEX African programme to prepare and implement joint activities under the Coordinated Observation and Prediction of the Earth System. Such joint initiatives will lead to a seamless suite of forecasts from short range weather to intraseasonal and seasonal outlooks to better satisfy the urgent need for integrated forecast information in decision systems. The THORPEX African programme will support the

observing component of the Year Of Tropical Convection (YOTC) initiative with AMDAR-Africa and promote the use of recent satellites products (e.g.; CloudSat) from the A-train constellation. It is also expecting to contribute to YOTC's forecasting component with forecast demonstrations targeting deep convection and heavy rainfall across the tropical regions of Africa using TIGGE and other related operational databases.

An African high impact weather information system will be built with the collaboration of the WMO Climate Data and Monitoring, Disaster Mitigation and Prevention programmes.

5.2 Links with AMMA, MEDEX and other regional projects

The African Monsoon Multidisciplinary Analysis project (Redelsperger et al. 2006) is an international project to improve knowledge, understanding and forecasting of the African monsoon. Working Group 5 of AMMA was established to contribute to THORPEX objectives over the monsoon region of Africa with AMMA extended and special observing periods datasets. Impacts of additional AMMA data particularly radiosondes on analyses and forecasts will be examined. Driftsondes, low cost sonde, dropsondes tests over West Africa were part of THORPEX observing system test experiments. Tests of targeting strategies with AMMA data on oversampled areas, forecast development and tailoring are activities of the AMMA-THORPEX working group. Late /early onset of rains breaks and bursts during the monsoon season, late /early withdrawal of the rains, heavy rains and floods are the main high impact events of interest to AMMA- THORPEX Working Group.

The MEDiterranean EXperiment is a project to document Mediterranean high impact weather and test forecasting systems. The THORPEX African programme will promote studies on the impact of tropical African weather features (heat low, tropical cyclogenesis and extra tropical cyclone transitions in the Atlantic, etc) on Mediterranean high impact weather. The interactions between convection in the African branch of the ITCZ, Rossby waves and subtropical frontal systems frequencies are major areas of investigations to understand the links between tropical, subtropical, midlatitude and polar weather systems. THORPEX Africa will promote European THORPEX - MEDEX joint initiatives over southern Europe and North Africa. The THORPEX African information system will use the MEDEX database over North Africa.

The Southern Hemisphere THORPEX is interested by African weather systems below the equator. Accurate prediction of South Indian Ocean cyclone tracks and severity, cut off lows, heat waves, severe thunderstorms, extremes cold and snow over southern Africa are major subject of collaboration between THORPEX Africa and the Southern Hemisphere THORPEX programme (Mc Bride et al. 2005). The Southern Hemisphere THORPEX database will contribute to the southern Africa component of the THORPEX African information system.

TIGGE and the potential GIFS will make available the full operational deterministic and ensemble data sets for research and demonstrations. To improve the operational value of TIGGE and GIFS, the THORPEX African programme will collaborate to increase these data sets with additional specific diagnostic fields (CAPE, CIN, Hovmoller diagrams, cross sections, etc) needed for targeted forecasts demonstration experiments in Africa. The African research community will be encouraged to use TIGGE and GIFS data sets in collaboration with operational centres. UCAR Africa initiative, UNESCO/ICTP physics of weather and climate programme are existing opportunities that promote training and research in Africa. The THORPEX African programme will promote high impact weather research and training in ICTP Affiliated centres in Africa in collaboration with UCAR.

The success of the societal, economic and environmental initiatives of the THORPEX African programme will be possible via partnerships with sensitive public and private organizations (UNISDR for disaster reduction, FAO for food security, etc). These partnerships will be built or strengthened over the lifetime of the African programme.

As a contribution to the UN year of planet Earth, the African programme will join the international community to promote the use of existing observations, analysis and forecasting tools

to improve understanding, modelling and forecasting of convection associated to high impact weather.

5.3 Cooperation with international weather centres

Given the limited research and development capabilities in Africa, international weather centres will be instrumental in providing data assimilation and modelling expertise for the African programme. Initiatives of the international THORPEX programme are promoting development of a Global Interactive Forecast System (Figure 12).

Under the leadership of WMO, the major international weather centres are committed to TIGGE. The THORPEX African plan will promote further collaboration for development and dissemination of specific operational support (i.e. real time provision of operational model outputs on dedicated websites, monitoring of observing system and stations performance...) during forecast demonstration experiments.

Moreover, the THORPEX African programme will work with the operational arm of TIGGE for the production and use of experimental forecast products based on the multi-model and ensembles from global/regional models. Currently, NAEFS and ECMWF provide global ensemble forecasts out to two weeks to a month.

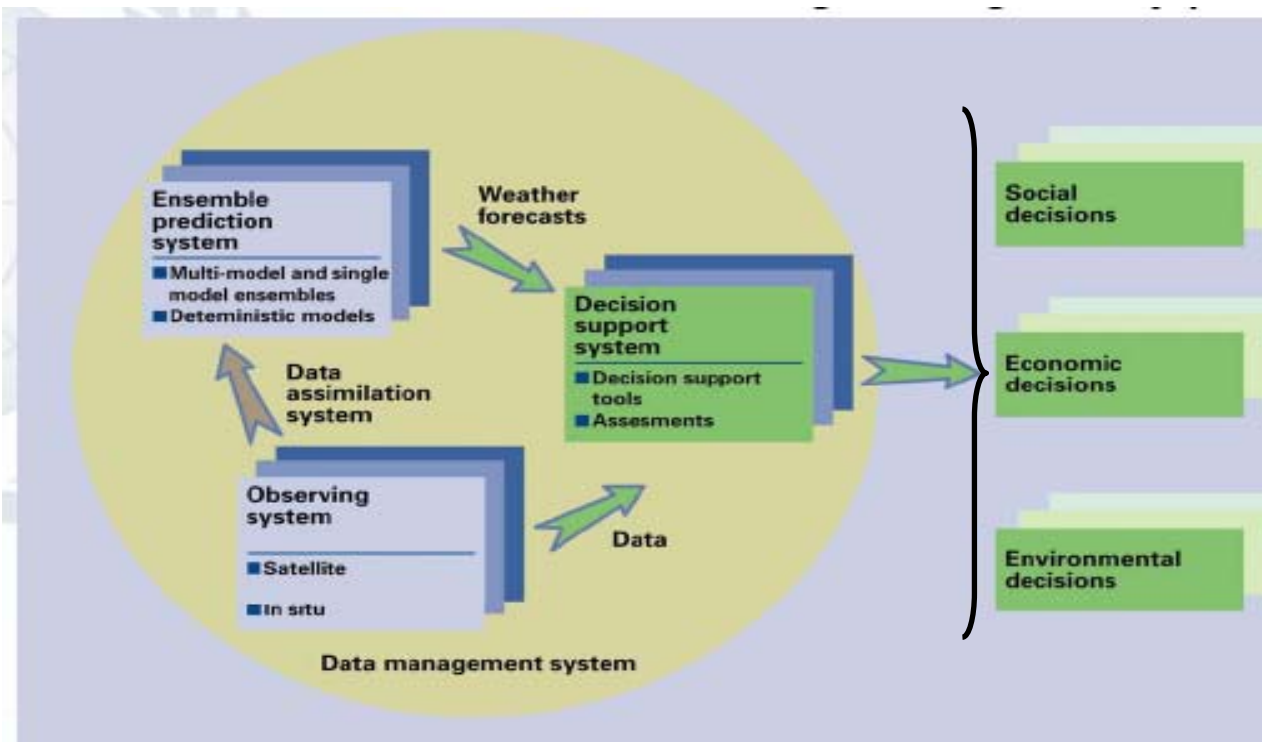


Figure 12. A global interactive end to end forecasting system for the 21st century

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CONTRIBUTORS

Mr Romain ROEHRIG, LMD at Pierre Simon Laplace Institute Paris, Coordinator of the first draft of THORPEX Africa Science Plan.

The following THORPEX African Task Force Members further developed the first draft to produce a revised Science Plan:

- **Mr Ousmane NDIAYE**, IRI at Columbia University New-York, Co-chair of SERA
- **Mr Mamina KAMARA**, Senegal Meteorological Service, Co-chair of SERA
- **Dr Ernest AFIESIMAMA**, Nigeria Meteorological Agency, Co-chair OS/DAOS
- **Dr Arona DIEDHIOU**, IRD- Niger, Co-chair OS/DAOS
- **Dr Aida DIONGUE NIANG**, Senegal Meteorological Agency, Co-chair PDP
- **Dr Benjamin LAMPTEY**, Ghana Meteorological Services Department, Co-chair PDP
- **Dr Andre KAMGA FOAMOUHOUE**, ACMAD-Niger, Coordinator

The following scientists provided contributions to prepare the current document:

David Burridge (WMO), Jim Caughey (WMO), Emilio Cuevas (INM Spain), Aïda Diongue-Niang (Senegal NMS), Joseph D. Intsiful (UK Met Office), Peter Knippertz (University of Cologne, Germany) Jean-Philippe Lafore (Météo-France), Benjamin Lamptey (NCAR), Zilore Mumba (ACMAD), Joseph Mutemi (University of Nairobi), Ousmane Ndiaye (IRI), Laban Ogallo (ICPAC), Franklin Opijah (University of Nairobi), Doug Parker (University of Leeds), Jean Pailleux (Météo-France), David Rogers (WMO), Chris Thorncroft (University at Albany), Adrian Tompkins (ICTP)

ACRONYMS

AAO	AntArctic Oscillation
ACMAD	African Centre for Meteorological Applications to Development
AEJ	African Easterly Jet
AEW	African Easterly Waves
AMDAR	Aircraft Meteorological DATA Reporting
AMMA	African Monsoon Multidisciplinary Analysis
ASECNA	Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar
CAS	Commission for Atmospheric Sciences
CBS	Commission for Basic Systems
CLIMDEV	CLIMate and DEVelopment
CLIVAR	CLImate VARIability project
CLOUDSAT	CLOUDs observation with SATellite mission of NASA
COF	Climate Outlook For a
COPT 81	Convection Profonde Tropicale en 1981
DCP	Data Collection Platform
ECMWF	European Centre for Medium range Weather Forecasts
ENSO	El Nino Southern Oscillation
EPS	Ensemble Prediction Systems
EUMETNET	EUropean METeorological services NETwork
EUMETSAT	European organization for exploitation of METeorological SATellites
FAO	Food and Agriculture Organization
FSU	Florida State University
GCOS	Global Climate Observing System
GEOSS	Global Earth Observing System of Systems
GIFS	Global Interactive Forecast System
GHACOF	Greater Horn of Africa Climate Outlook Fora
GLA	Goddard Laboratory for Atmospheres - NASA
GPS	Global Positioning System
GTS	Global Telecommunication System
ICSU	International Council for Scientific Union
ICTP	International Centre for Theoretical Physics
IOC	Intergovernmental Oceanographic Commission of UNESCO
ITCZ	InterTropical Convergence Zone
JSC	Joint Steering Committee
MEDEX	MEDiteranean Experiment on cyclones

METOP	Meteorological Operational Polar Satellite
MDD	Meteorological Data Distribution
MDGs	Millennium Development Goals
MJO	Madden Julian Oscillation
MSG	Meteosat Second Generation
NAO	North Atlantic Oscillation
NAEFS	North American Ensemble Forecasting System
NASA	National Aeronautic and Space Administration
NCEP	National Centre for Environmental Prediction
NGO	Non Governmental Organization
NMHSs	National Meteorological and Hydrological Services
NRC	National Research Council of the US
NRL	Naval Research Laboratory in Monterey-California
NWP	Numerical Weather Prediction
OSE	Observing System Experiment
PRESAO	PREvision Saisonnière en Afrique de l'Ouest
PUMA	Preparation for Use of Meteosat in Africa
QBO	Quasi Biennial Oscillation
RANET	RAdio and InterNET
RA1	Regional Association 1
SARCOF	Southern Africa Regional Climate Outlook Fora
SOP	Special Observing Period
SUNY	State University of New York
SST	Sea Surface Temperature
TEJ	Tropical Easterly Jet
THORPEX	THE Observing system Research and Predictability Experiment
TIGGE	THORPEX Interactive Grand Global Ensemble
TMRP	Tropical Meteorological Research Programme
UNESCO	United Nations Education, Science and Culture Organization
UCAR	University Corporation for Atmospheric Research
UNISDR	United Nations International Strategy for Disaster Reduction
WAM	West African Monsoon
WCRP	World Climate Research Programme
WGNE	Working Group on Numerical Experimentation
WMO	World Meteorological Organization
WWRP	World Weather Research Programme
WWW	World Weather Watch programme
YOTC	Year Of Tropical Convection

LIST OF THORPEX SERIES PUBLICATIONS

1. International Core Steering Committee for THORPEX. Third Session. 16-17 December 2003, Montreal, Canada. Final Report. WMO/TD-No. 1217, WWRP/THORPEX No. 1.
2. M.A. Shapiro, A.J. Thorpe, 2004: THORPEX International Science Plan Version 3. WMO/TD-No.1246, WWRP/THORPEX No. 2.
3. International Core Steering Committee for THORPEX. Fourth Session 2-3 December 2004, Montreal, Canada. Final Report. WMO/TD-No. 1257, WWRP/THORPEX No. 3.
4. THORPEX International Research Implementation Plan Version 1. WMO/TD-No. 1258, WWRP/THORPEX No. 4.
5. First Workshop on the THORPEX Interactive Grand Global Ensemble (TIGGE), Reading, United Kingdom, 1-3 March 2005, WMO/TD No. 1273, WWRP/THORPEX No.5.
6. Symposium Proceedings - The First THORPEX International Science Symposium, 6-10 December 2004, Montreal, Canada, WMO/TD 1237 WWRP/THORPEX No. 6.
7. Symposium Proceedings – The Second THORPEX International Science Symposium, 4-8 December 2006, Landshut, Bavaria, Germany, WMO/TD No. 1355, WWRP/THORPEX No. 7.
8. International Core Steering Committee for THORPEX. Sixth Session 25-27 April 2007, Geneva, Switzerland. Final Report. WMO/TD No. 1389, WWRP/THORPEX No. 8.
9. The YOTC Science Plan – A Joint WCRP-WWRP/THORPEX International Initiative. WMO/TD No. 1452, WCRP-130, WWRP/THORPEX No. 9.

For more information, please contact:

World Meteorological Organization

Research Department

7 *bis*, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland

Tel.: +41 (0) 22 730 81 11 – Fax: +41 (0) 22 730 81 81

E-mail: AREP-MAIL@wmo.int – Website: http://www.wmo.int/pages/prog/arep/index_en.html