

# JOINT WMO TECHNICAL PROGRESS REPORT ON THE GLOBAL DATA PROCESSING AND FORECASTING SYSTEM AND NUMERICAL WEATHER PREDICTION RESEARCH ACTIVITIES FOR 2009

## Tanzania Meteorological Agency (TMA) United Republic of Tanzania

### 1. Summary of highlights

This report describes the essential features of the numerical weather prediction (NWP) system operational at the Tanzania Meteorological Agency (TMA) during the year 2009. The system is based on the WRF and HRM NWP systems, maintained by the Agency (<http://www.meteo.go.tz>).

Major changes in operational data processing and forecasting system in 2009:

Date	Event
October 2009	Operation of new version of WRFV3.0 model.
November 2009	Operation of new version of HRM Version.
December 2009	WRF (BOGUS) for Tropical cyclone track and intensity operation over tropical- western Indian Ocean. (southwest Indian Ocean basin)

### 2. Equipment in use

There are three computers dedicated to the operation of short-range numerical weather prediction.

#### 2.1 DELL POWEREDGE SC2970 SERVER

**Operating system:** – Red Hat Enterprises Linux Server (2.6.18)

**CPUs and performance**

Two 2.5GHz – core Processors

**Memory**

System Memory size 4.0GB, System Memory speed 667MHz

**Disk storage**

Direct-attached storage: 584GB

#### 2.2 DELL POWEREDGE SC1430 SERVER

**CPUs and performance**

Two 1.86 GHz – core processors

**Operating system:** LINUX - Fedora Core 5

**Memory**

System Memory size 4.0GB, System Memory speed 667MHz

**Disk storage**

Direct-attached storage: 500GB

#### 2.3 HP XW4400 WORKSTATION

**CPUs and performance**

1.86 GHz – core processors

**Operating system:** LINUX - Fedora Core 5

## Memory

System Memory size 1.0GB, System Memory speed 667MHz

## Disk storage

Direct-attached storage: 160GB

### 3. Data and products from GTS in use

Synoptic observations and upper air observation, including satellite and wind profiler data, are used on a daily basis for forecasting and verification. Pre-processing procedures such as data acquisition and decoding are not fully automated and this becomes a blocking mechanism for data assimilation in the daily operational runs.

- SYNOP
- SHIP
- BUOY
- AIREP
- TEMP

### 4. Forecasting system

#### 4.1 System run schedule and forecast ranges

##### Short- and medium-range forecast

At TMA NWP system runs based on 00UTC analyses for the forecast length of 48 to 78 hours depending on the type of the model. WRF (USA model) runs for 48 hours with the resolution of 15km for the (course domain) bigger domain and for 5km (for the nested one) for smaller one. Sometimes 72 hours forecast is also conducted depending on the atmospheric situation. HRM (German model) runs for 72 hours at 00UTC. Initial boundaries condition for WRF are generated from NCEP GFS at 1x1 degree, while HRM initial condition are obtained from GME

Model	Version	Resolution	Forecast length	Initial and boundary conditions	Comment
WRF	3.1	5-15km	48-54	NCEP	Daily run
WRF BOGUS	3.0 TC track	10 km	48-72 hours	NCEP	During TC
HRM	2.4	14km	78 hours	GME	Daily run

##### Long-range forecast

No operational runs

#### 4.2 Medium-range forecasting system (4-10 days)

##### 4.2.1 Data assimilation, objective analysis and initialization

###### 4.2.1.1 In operation

No operational run in 2009.

###### 4.2.1.2 Research performed in this field

##### Evolution of tropical cyclone over Southwest Indian Ocean using Data Assimilation

Tropical cyclones (TC) relate to the most intense meso-scale features in tropical atmosphere. Wind speed in them can reach over 50 m/s, which can lead to significant economic damage and human losses if the tropical

cyclone crosses the land. According to statistics of the UN on major natural disasters that have occurred in the world over the past 50 years, tropical cyclones accounted for 30% of the extensive damage, 19% of the loss of life and 20% of the total number of victims. The forecasted trajectories, place and time where the tropical cyclones would cross the land could allow the evacuation of people and property from the region of approaching disaster.

The Southwest Indian Ocean has an average of about 10 tropical cyclones per year, however very few researches have been conducted in this region compared to other tropical regions. Numerous experiments using different approaches have been conducted at the northern hemisphere so as to improve the forecast of trajectories and intensity of the tropical cyclones.

Forecast of trajectory and intensity change for mature tropical cyclones requires accurate representation of the tropical cyclone vortex in the model initial conditions. Tropical cyclone originates and moves over sea and ocean waters where ground based meteorological observation station are very few or not present. Vortices contained in the large scale analyses from operational centres are often too broad, weak and sometimes misplaced. In addition, observations in the vicinity of the tropical cyclones are usually sparse thus leads to major difficulties in numerical prediction of tropical cyclones in model initialization.

One of the most common approaches to improving the quality of input data for numerical simulations - is the use of data assimilation procedures (i.e. combining observational data with results of model background field). However, as practice shows, the quality of forecasting intensity and trajectory of the tropical cyclones depends not only on the accuracy of model background field and the chosen method of data assimilation, but also on the reliability of initial information about the cyclone itself (such as its position, minimum central pressure, maximum wind speed, the size of the tropical cyclone etc).

In order to improve the storm representation, the use of bogus vortices is often adopted Waniha et al (2009) - <http://jhwc.snu.ac.kr/wrf2009/wagenda.htm> and Waniha and Smishlyev (2009), *in Russian*, where they studied the impact of Bogus Data Assimilation (BDA) methods over Southwest Indian Ocean. The main strategy of this scheme is to change the poorly resolved vortex from a coarse resolution analysis to a more realistic vortex that is constructed to better match the high resolution analysis. In bogus procedure, tropical cyclone vortex is artificially introduced according to the size of the cyclone (the radius of maximum winds), its position and central Sea Level Pressure.

In this study, with the increase usage of WRF model in East African countries including Tanzania, the impact of BDA in simulating tropical cyclones (which is one of the most disastrous weather phenomena) over Southwest Indian Ocean region will minimize the disaster risk.

The initialization scheme which is designed to improve the representation of a tropical cyclone in the initial condition is tested during landfalling Tropical Cyclone Bondo (2006) over Southwest Indian Ocean using WRF version 3.0. A series of numerical experiments are conducted to generate initial vortices by assimilating the bogus wind and pressure information into WRF. The scheme produced an initial vortex that was well adapted to the forecast model and was much more realistic in terms of size and intensity than the storm structure obtained from the NCEP analysis. Using this scheme with different cold start time for the non-vortex initialized case starting from the NCEP global analysis without and with assimilation (Control Run), 3DVAR and cycling run the forecast errors for initial position of the tropical cyclone, central pressure and maximum wind speed were much larger compared to the forecast error with the vortex initialized case.

For a tropical cyclone prediction, a correct warning of a landfall time, location and intensity is the most important issue in preparing for evacuation. In Southwest Indian Ocean, more percentage of the damages caused by tropical cyclones occurs during the landfall. Consequently bogus effect in landfall prediction is investigated. The results showed that the use of bogus scheme did not only improve the initial conditions of the tropical cyclone but also improved the position and the time of the tropical cyclone landfall significantly.

## **4.2.2 Models**

WRF version 3 and HRM are used operationally.

### **4.2.2.2 Research performed in this field**

As in section 4.2.1.2 above.

### **4.2.3 Operationally available Numerical Weather Prediction products**

Analysis, forecast, and auxiliary weather charts and various graphic images were produced from NWP post-process system and distributed to the forecasters and the public. TMA's NWP products on real time base are offered via TMA website (<http://www.meteo.go.tz>).

Apart from WRF and HRM products that TMA is running at NWP section, other NWP's products are available (obtained) from other regional and global centres. Under on-going Severe Weather Demonstration Forecast Project (SWFDP) over Southern African countries more products from European and USA models are available (<http://old.weathersa.co.za/RSMC/login.jsp>). The regional guidance products available are Unified Model with 12km resolution (UMSA12), Unified model Africa LAM at 20km resolution (ALAM) and ALADIN from LA Reunion, while global products are from NOAA Global Forecasting System (NOAA-GFS), Ensemble Prediction Systems from ECMWF (ECMWF-EPS), Met. Office (UK MET OFFICE-EPS) and South African Weather Service (SAWS-EPS). Another product from Met Office Global and Regional Prediction Scheme (**MOGREPS**) ensemble forecasting system are also used for the interpretation.

### **4.2.4 Operational techniques for application of NWP products (*MOS, PPM, KF, Expert Systems, etc.*)**

#### **4.2.4.1 In operation**

These operational techniques are used implicitly in different NWP products and are automatically generated from NWP model (WRF and HRM).

#### **4.2.4.2 Research performed in this field**

No activity in this area

### **4.2.5 Ensemble Prediction System (EPS)**

#### **4.2.5.1 In operation**

#### **4.2.5.2 Research performed in this field**

No activity in this area

#### **4.2.5.3 Operationally available EPS Products**

No activity in this area

## **4.3 Short-range forecasting system (0-72 hrs)**

### **4.3.1 Data assimilation, objective analysis and initialization**

#### **4.3.1.1 In operation**

No activity in this area

#### **4.3.1.2 Research performed in this field**

No activity in this area

### **4.3.2 Models**

#### **4.3.2.1 In operation**

No activity in this area

#### **4.3.3 Operationally available NWP products**

See 4.2.3

#### **4.3.4 Operational techniques for application of NWP products**

##### **4.3.4.1 In operation**

No activity in this area

##### **4.3.4.2 Research performed in this field**

No research performed in this area

#### **4.3.5 Ensemble Prediction System**

##### **4.3.5.1 In operation**

No short-range EPS system is in operation at TMA.

##### **4.3.5.2 Research performed in this field**

No research performed in this area

##### **4.3.5.3 Operationally available EPS Products**

See 4.2.3

#### **4.4 Nowcasting and Very Short-Range Forecasting Systems (0-6 hrs)**

##### **4.4.1 Nowcasting system**

###### **4.4.1.1 In operation**

No nowcasting system is in operation at TMA.

###### **4.4.1.2 Research performed in this field**

No research performed.

##### **4.4.2 Models for Very Short-range Forecasting Systems**

###### **4.4.2.1 In operation**

No system is in operation at TMA.

###### **4.4.2.2 Research performed in this field**

No research performed.

#### **4.5 Specialized numerical predictions**

##### **4.5.1 Numerical prediction system for tropical cyclone**

New numerical prediction system for tropical cyclone (Bogus Data Assimilation) was introduced late 2009 and TMA is monitoring the performance during the current tropical cyclone season till end of April 2010.

##### **4.5.2 Ocean wind wave prediction systems**

No activity in this area

#### **4.6 Extended range forecasts (ERF) (10 days to 30 days)**

##### **4.6.1 Models**

###### **4.6.1.1 In operation**

No activity in this area

#### **4.6.1.2 Research performed in this field**

No activity to report

#### **4.6.2 Operationally available NWP model and EPS ERF products**

Nothing to report

#### **4.7 Long-range forecasts (LRF) (30 days up to two years)**

##### **4.7.1 In operation**

TMA issues two types of long range forecasts – monthly and seasonal forecasts, by using interpretation of the global and other regional model products.

##### **4.7.2 Research performed in this field**

No research performed in NWP.

##### **4.7.3 Operationally available EPS LRF products**

See 4.2.3

### **5. Verification of prognostic products**

#### **5.1 Annual verification summary**

The summary of annual verification statistics are done only for daily weather and seasonal forecasts including the WRF maximum and minimum temperature forecasts against observations. In this report seasonal forecast verification is not presented.

Daily maximum and minimum temperature forecasts during June-August (JJA) 2008 and March- May (MAM) 2009 issued at Central Forecast Office are verified against observations. The WRF model maximum and minimum temperature forecasts are also verified against observations. The daily forecast and observed temperatures for three consecutive months of June, July and August (JJA) of 2008 and March, April and May (MAM) of 2009 were collected for the purpose of verifying. There are different forecasting methods and these include persistency, climatology, statistical, trend method, analogue, dynamical (NWP) and among others. In this present report persistence method used was verified. The categorical statistical and continuous statistic methods were used. The biases of daily temperatures during these periods of verification were examined to see the deviation from the observed temperatures. In this report six selected stations (Dar es Salaam Julius Nyerere International Airport (JNIA), Tanga, Pemba, Morogoro, Pemba and Handeni) were considered over northern coast part of the country. The frequency of biases was translated into three categories: CORRECT, SATSFACTORY and INCORRECT. The forecast is CORRECT when the bias is between 0 and  $\pm 1.0$ , SATSFACTORY when is between  $\pm 1.0$  and  $\pm 2.0$  ( $-1.1$  and  $\pm 2.0$  or  $1.1$  and  $\pm 2.0$ ), and INCORRECT when the bias is otherwise.

The verification from persistency method shows that percentage of correct forecasts during the period of June-July 2008 for JNIA is 64.1%, for Morogoro is 46.7%, for Tanga is 70.7%, for Pemba is 81.5%, for Handeni is 52.2% and the overall is 63.1%. During the months of March-May 2009, the percentage of correct forecasts for JNIA is 55.4%, for Morogoro is 60.9%, for Tanga is 61.9%, for Pemba is 75%, for Handeni is 55.4% and the overall is 61.7%.

During these two periods, verification of maximum and minimum temperature forecasts by WRF is that it is generally under-estimating for maximum temperature while for the minimum temperature the model is over estimating.

#### **5.2 Research performed in this field**

No activity in this field

## **6. Plans for the future (*next 4 years*)**

### **6.1 Development of GDPFS**

#### **6.1.1 Major changes in operational DPFS expected in the next year**

To produce more accurate, timely and reliable weather forecasts and warnings over the country.

##### **Assimilation of synoptic data in NWP including remote-sensing (RADAR)**

In Tanzania there is ongoing national project for enhancing capability and infrastructure in respect of NWP activities whereby seven RADARs are planned to be procured starting from this year of 2010. Towards the end of this year one RADAR is expected to operate and will be useful in forecasting including improvement of initial and boundary condition.

At the moment no data assimilation is in operational due to technical know how; however data format from 27 synoptic stations **including** 7 operating Automatic Weather Stations and automation of data transmission system to national central forecast Office is still a challenge. In the process of data assimilation RADAR observations are planned to be anticipated. We also expect to study the performance of BOGUS in WRF Version 3.2 (latest version) over Southwest Indian Ocean in forecasting the trajectory and intensity of Tropical cyclone.

Other changes expected in the next year are the operational access to NWP products from major centres and effective use and interpretation of all NWP products forecasting operations

#### **6.1.2 Major changes in operational DPFS envisaged within the next 4 years**

##### **Enhancement of NWP section to produce better forecasts and warnings for Disaster Risk Reduction in the country**

Ongoing national project for enhancing capability and infrastructure in respect of NWP activities can be realized by performing the following activities.

1. Modernization of computing systems, from lower-speed category to a higher-speed computing system.
2. Automatic data reception to national central forecasting office, decoding and archival; automatic data visualization; and automatic data processing.
3. Improving the assimilation of synoptic data in NWP including remote-sensing
4. Operational access to NWP products from major centres
5. Effective use and interpretation of all NWP products forecasting operations
6. Operational nowcasting system for high impact weather warning

### **6.2 Planned research activities in NWP, nowcasting and long-range forecasting**

#### **6.2.1 Planned research activities in NWP**

1. Development of verification tools
2. Research on impact of near-surface scheme in NWP
3. The performance of various convective schemes study for wet and dry seasons over different regions of the country

The impact of various satellite data will be tested in 2011/12. Infrared Atmospheric Sounding Interferometer (IASI) temperature and humidity and Advanced Scatterometer (ASCAT) winds from Meteorological Operational satellite (METOP) will be examined for operational use. The expected increased TMA Automatic Weather Station (AWS) network and RADAR information expected to be used for the high resolution limited area model. The verification tools for estimating the impact of observation will be developed to improve the reliability of evaluation and validation. Downscaling of global model projection to regional level is also expected to be performed.

### **6.2.2 Planned research activities in nowcasting**

From 2011, a precipitation and thunderstorm nowcasting based on a nonhydrostatic mesoscale model output, satellite (using SUMO software developed in South Africa for satellite information processing) and RADAR observation will be issued by the correction of model errors (phase and intensity errors).

### **6.2.3 Planned research activities in long-range forecasting**

The primary objective of NWP section is to coordinate weather and climate modeling and verification with a view to enhancing the capacity of the Agency to generate and evaluate weather/climate outlook forecasts, provide more detailed operational forecasts and improve accuracy. Some of activities planned to be carried out during the coming four years to come are:

1. Dynamical downscaling of global seasonal forecasts to regional/national level that takes into account the local climatology. To improve the detailed physiographic information about the surface in surface block (orography and physiography in surface physics including boundary layer and their impact on convective activities)
2. Enhance sub-regional scientific collaboration in NWP activities through joint projects.

## **7. References**

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3. <http://jhwc.snu.ac.kr/wrf2009/wagenda.htm>