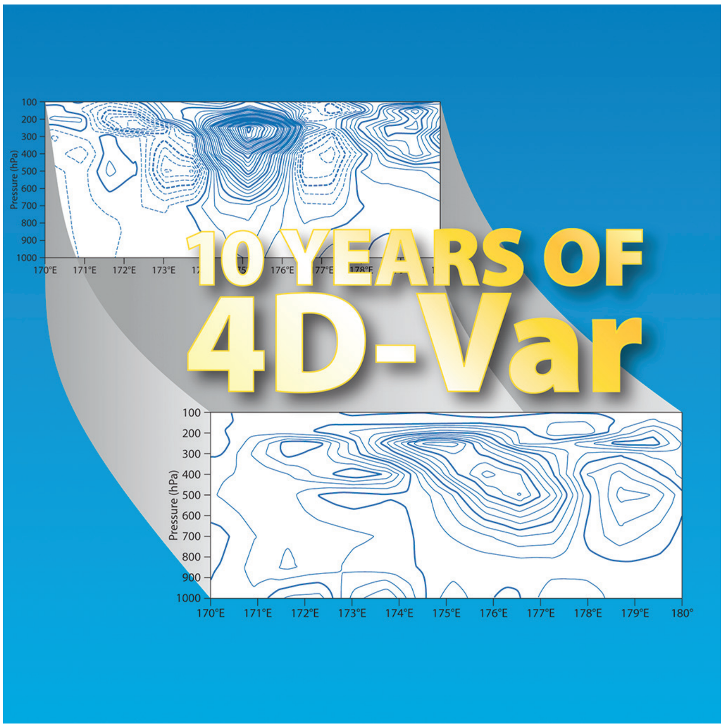
ECMWF Feature article

from Newsletter Number 115 – Spring 2008

METEOROLOGY

ECMWF’s contribution to AMMA



www.ecmwf.int/en/about/news-centre/media-resources

doi:10.21957/28vtm6dpt6

This article appeared in the Meteorology section of ECMWF Newsletter No. 115 – Spring 2008, pp. 19-27.

ECMWF's contribution to AMMA

Anna Agustí-Panareda, Anton Beljaars

The African Monsoon Multidisciplinary Analysis (AMMA) is an international project whose main focus is to improve the prediction of the West African Monsoon and its socio-economic impact on West African nations, as well as improving our understanding of fundamental scientific issues, such as the monsoon variability on diurnal, intra-seasonal, inter-annual and decadal scales.

Based on a French initiative, AMMA was built by an international scientific group and is currently funded by a large number of agencies, especially from France, UK, USA and Africa. It has been the beneficiary of a major financial contribution from the European Community's Sixth Framework Research Programme. This funding has allowed ECMWF to have a consultant to work full-time on the AMMA project. Detailed information on scientific coordination and funding is available on the AMMA International web site at: www.amma-international.org.

Between 400 and 500 scientists from more than 25 countries, representing more than 140 agencies and institutions, are involved in AMMA. A network of African scientists linked to AMMA has been established to consolidate existing collaborations in Africa.

Purpose of AMMA and ECMWF's role

The West African Monsoon (WAM) provides most of the rainfall for West African countries, in particular those in the region of the Sahel with an agriculturally-based economy which is very much dependent on rain-fed crops. Sahel had long-lasting drought leading to widespread crop failure and famine in the 1980s and 1990s. Thus, predicting the rainfall season is crucial for farmers and aid planning. The WAM also encompasses very interesting meteorological phenomena. During the wet monsoon season the region has often been depicted as a natural laboratory for convection. About 40% of Atlantic tropical cyclones originate from mesoscale convective systems (MCS) embedded in synoptic-scale African Easterly Waves (AEWs). These MCS are also important for the troposphere-stratosphere exchange through deep convection.

The study of the complex interaction of all monsoon components on different spatial and time-scales (e.g. the continental Intertropical Convergence Zone (ITCZ), the African Easterly Jet (AEJ), the AEWs, the Saharan Air Layer (SAL), convection and land-surface processes) is one of the main scientific aims of AMMA. Other topics of interest are the important role of atmosphere and land-surface coupling and soil moisture, and the global impact of dust transport within the SAL and aerosols from biomass combustion. For more information on the aims and organization of the AMMA project see *Redelsperger et al.* (2006) and http://amma.mediasfrance.org/index.

Due to the complex physical interaction between different components of the WAM, and the lack of data available in the West African region, forecasting the WAM and precipitation in particular remains a challenge. This is reflected in systematic errors in the short-range, medium-range and seasonal forecasts. In order to improve our understanding and the forecast of the monsoon season it is important to have access to observations, in particular radiosonde observations which are currently the only means of providing comprehensive vertical thermodynamic and wind profiles in the troposphere. The poor status of the meteorological observing system in West Africa, due to lack of infrastructure and telecommunication problems, means that the number of observations that reach the Global Telecommunications System (GTS) is very low. This has a direct impact on the quality of the analyses and forecasts.

AMMA scientists have been working with operational agencies in Africa to reactivate silent radiosonde stations, renovate unreliable stations and install new stations in regions of particular climatic importance. During the AMMA field experiment in 2006 there was the monitoring of 26 stations (Figure 1). From those, 21 stations were active from June to September 2006 and some 7,000 soundings could be made (Figure 2). This represented the greatest density of radiosondes ever launched in the region; even greater than during GATE (GARP Atlantic Tropical Experiment) in 1974.

Our activities related to AMMA are strongly embedded in ECMWF's core activity of data assimilation and medium-range weather forecasting. Many people in various sections at ECMWF have directly or indirectly contributed. There is also a strong link with other partners in the AMMA project, not least because many partners make use of ECMWF analyses for their studies.

Anna Agustí-Panareda is supported by the European Union project AMMA.

doi:10.21957/28vtm6dpt6

The main activities at ECMWF have been:

- Monitoring the radiosonde network in West Africa.
- Developing a radiosonde humidity bias correction scheme.
- Evaluating the medium-range forecasts for West Africa.
- Performing a special AMMA reanalysis and data impact studies.

There are also supporting activities such as:

- Placing real-time forecast plots for AMMA participants on the web, aimed at supporting forecasters in the West African region, in particular forecasters from the African Centre of Meteorological Application for Development (ACMAD) in Niamey, Niger.
- Providing model output to the AMMA Model Intercomparison Project (AMMA-MIP).
- Finally, collaboration with other projects including ARM, THORPEX and ENSEMBLES has led to the exchange of valuable observations (e.g. ARM mobile facility and driftsondes) and model output from the seasonal forecast models.

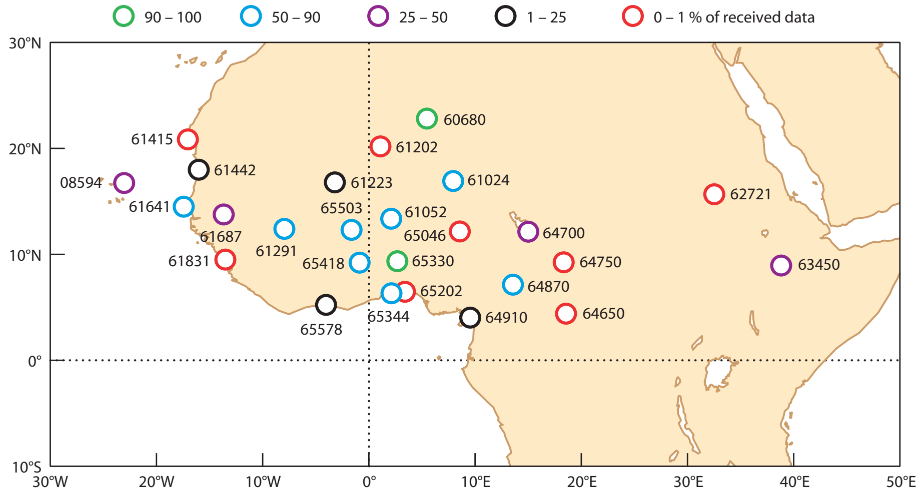


Figure 1 Radiosonde stations monitored in the AMMA project based on 700 hPa temperatures from the 00 and 12 UTC soundings for August 2006 which was during the AMMA Special Observing Period in 2006. Colours indicate the percentage of data received at ECMWF mainly via the GTS. Additional radisonde TEMP reports were also received via email.

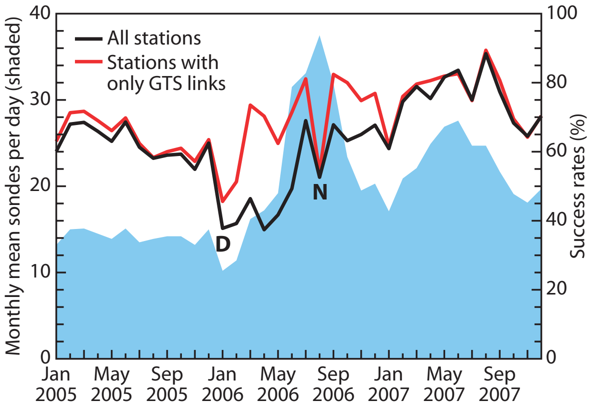


Figure 2 Shaded area: Numbers of soundings (monthly mean sondes per day) acquired operationally by ECMWF from the AMMA network from January 2005 to November 2007. Black line: Percentage success rate of data reception for the 21 primary stations in the network. Red line: Percentage success rate excluding the 4 stations with no direct GTS link that used satellite and email transmission. 'D' identifies the effects of a GTS failure at Dakar, while 'N' denotes lightning damage at Niamey which interrupted transmission for several stations (from *Parker et al.*, 2008).

Monitoring the radiosonde network in West Africa

Failure in data reception over Africa can be due to communication problems which can often be resolved if there is a timely report of reception failure. Thus, one of the most critical aspects of monitoring is to find out which stations are reporting to the GTS and which stations are not. At ECMWF, data reception from radiosondes is monitored by producing a monthly table with information on radiosonde TEMP messages received each day. All the monthly tables from January 2005 onwards are available on the website at: www.ecmwf.int/amma/d/ammatab.

From March 2006, alarm bells and summaries of the data reception have been issued by email to the radiosonde core group responsible for contacting the relevant station operators. There are three types of emails: daily check, three-day check and weekly summary.

- ***Daily check.*** This is an alarm bell issued when more than half of the stations considered to be reliable are not reporting. In that case, it is likely that the reception failure is due to a general communication problem in the GTS hub.
- ***Three-day check.*** This is an alarm bell for individual stations that have not reported for more than three days, indicating a possible local problem with a particular station.
- ***Weekly check.*** This contains information on the number of soundings received, planned and missing, as well as the percentage of success in data reception.

The monitoring tables can help to assess (a) the continuity of radiosonde datasets, (b) the frequency of soundings and (c) whether the complete information on the soundings has been received. In the pre-AMMA period most stations were only launching one sounding per day, but during the AMMA period most stations had two soundings per day and a subset of stations had four soundings per day. During 20–29 June 2006 and 1–15 August 2006 the frequency of soundings increased to 8 per day at 6 stations along a north-south transect from the Guinea coast to the desert. Details of the AMMA effort on the radiosonde network in West Africa are presented in *Parker et al.* (2008).

The quality of the data was assessed by computing statistics of departures between the observations with respect to the model short-range forecast and the model analysis. Tephigrams and monthly vertical statistics are available in near real time for all 21 AMMA radiosonde stations (see www.ecmwf.int/products/forecasts/d/charts/monitoring/amma/). The monitoring of the departures between observations and model shows the following.

- There is up to 20% negative bias in the relative humidity between the observations and the first guess during the monsoon season over the Sahel below 700 hPa. This is partly due to a dry bias in the Vaisala RS80 radiosondes and partly due to an overestimation of model relative humidity. The statistics for MODEM radiosondes also show a dry bias at low-levels, as well as a larger moist bias around 500 hPa.
- The winds at the level of the African Easterly Jet (AEJ), which is at about 700 hPa, tend to deviate anticlockwise by 20° in the model first guess during the monsoon season in the Sahel. On average during August the AEJ is oriented from east to west in the observations, which means the 700 hPa winds in the ECMWF model tend to have a stronger northerly component than the observations over the Sahel.
- Stations launching balloons to only measure wind profiles produce very noisy soundings, many reporting data at very few levels. Therefore, many such stations in northwest Africa have been blacklisted.

Radiosonde humidity bias correction in the AMMA region

Almost half of the radiosondes assimilated were Vaisala RS80 which are known to have a substantial dry bias at both lower and upper troposphere (*Wang et al.,* 2002). This is an important issue as dry radiosonde humidity bias can have a detrimental impact on NWP models, in particular on cloud cover and precipitation (*Lorenc et al.,* 1996). The dry bias also affects the ECMWF analysis increments of specific humidity which are negative around radiosonde stations. This could lead to the southward shift of the ITCZ over Africa in the ECMWF short-range forecast which has too little precipitation over the Sahel. All this has motivated the development and application of a radiosonde humidity bias correction.

Four main types of radiosondes were used operationally during the AMMA field experiment with six different WMO code types: Vaisala RS80 and RS92, VIZ and MODEMs. From the 21 radiosonde stations that were active from May to September 2006, 9 of them used Vaisala RS80 sondes, 3 used a mixture of Vaisala RS80 and RS92, 3 used Vaisala RS92, 5 used MODEM sondes and 1 used VIZ sondes.

Creating the new humidity bias correction scheme

Previous studies have used a variety of empirically and physically-based methods of radiosonde humidity bias correction for specific radiosonde sensor types using independent reference data from research instruments during field and laboratory experiments. We have developed an empirically-based method that can work operationally and globally for any radiosonde type by using the ECMWF short-range forecast as an intermediary dataset for computing biases. The main reasons for developing a new correction scheme operationally and for the future AMMA reanalysis are:

- Many radiosonde types have been used in the AMMA field experiment and not all of them are well documented.
- Operationally not all the additional metadata required to apply the existing humidity bias correction schemes is available.
- ECMWF analyses compare well with independent Total Column Water Vapour (TCWV) derived from Global Positioning System (GPS) data (*Bock et al.,* 2007).

The bias correction coefficients are based on the difference between the bias of the sonde type to be corrected and the bias of a reference sonde at night-time. Such a scheme has been recently implemented operationally to correct the radiosonde humidity and temperature bias in ECMWF IFS cycle 32r3 (see *Bechtold et al.,* 2008). The scheme is developed further for the West African region in view of the future AMMA reanalysis by considering the dependency of the humidity bias on the value of the observed humidity. Previous studies have shown that humidity biases associated with radiosonde observations depend on the observed relative humidity (RH), as well as sonde type, solar elevation, temperature, age of radiosonde and pressure. Over the Sahel, the variation of RH bias with the observed RH is particularly strong due to the pronounced seasonal cycle. Scatter plots of short-range forecasts – used as first guess in the data assimilation – versus observed values also reveal that the RH bias varies with observed values as shown in Figure 3(a). Thus, this refined bias correction is computed for all sonde types used in the AMMA field experiment within the geographical area from 5°S to 35°N and 25°W to 40°E using data from January 2005 to July 2007.

Relative humidity biases vary with sonde type, solar elevation and pressure level. Thus, the humidity bias for each of these categories is computed separately. In order to compute the bias we have adopted the technique of equiprobability transform also known as Cumulative Distribution Function (CDF) matching. The observed RH is transformed from its original CDF to another CDF which here is given by the model short-range forecast of RH. The bias is thus found by plotting quantile-quantile (QQ) plots obtained by matching the CDF of the observations and CDF of the model first guess. Figure 3(b) illustrates this. The bias correction is computed by subtracting the bias function of the reference sonde from the bias function associated with the observed sounding. The reference sonde used is the Vaisala RS92 at night-time, i.e. the same as in the operational radiosonde bias correction scheme. Vaisala RS92 sondes are one of the most accurate operational radiosondes and are now widely used.

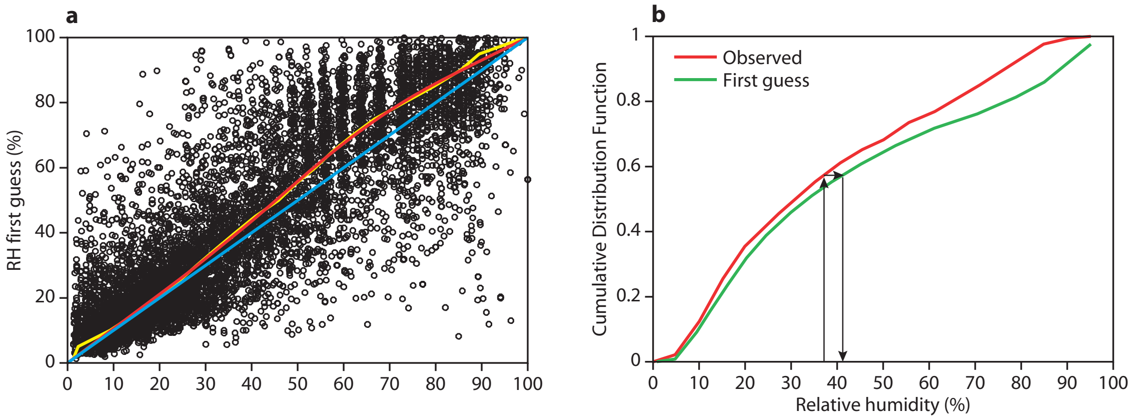


Figure 3 a) Scatter plot of first guess versus observed relative humidity (%) for Vaisala RS80 Digicora I, II radiosondes at 925 hPa and for positive solar elevations. The coloured curves show the identity line (blue), the bias obtained from Cumulative Distribution Function (CDF) matching (yellow) and the best fit using four sine waves (red). (b) Cumulative distribution function for observations (red) and first guess (green). Arrows illustrate the CDF matching technique described in the text.

Evaluating the new humidity bias correction scheme

In order to evaluate the new radiosonde bias correction scheme, two analysis experiments at resolution T511 (~40 km) and 91 vertical levels have been performed using the ECMWF IFS Cy32r3.

- The control experiment has no humidity bias correction; it uses only the old temperature bias correction.
- The bias correction experiment has the new operational radiosonde temperature and humidity bias correction as well the new AMMA bias correction procedure.

Comparison of observation biases with respect to first guess and analysis for the two experiments with and without humidity bias correction are shown in Figure 4 for Vaisala RS80 sondes at Dakar. The observed RH bias with respect to the model is greatly reduced after applying the humidity bias correction. The negative analysis increments – shown by the difference between the dotted and solid lines – are also greatly reduced. Thus, the drying effect of the observed RH on the humidity analysis is much smaller. As expected, the bias correction generally reduces the bias at low-levels more than at upper-levels, due to the upper-level dry bias associated with Vaisala RS92 at night-time which is not corrected here. The impact of radiosonde RH bias correction on NWP analysis and forecast is also significant.

By reducing the dry bias of the AMMA radiosonde stations, the TCWV in the analysis increases by between 1 and 4 kg m–2 (Figure 5). The increase in moisture is mainly located around the Vaisala RS80 stations. These stations are in the vicinity of the steep meridional moisture gradient over the northern Sahel region. Thus, the dry bias can also have an impact on the location and magnitude of this gradient. The humidity bias correction has a larger impact on TCWV during daytime (12 UTC) when the dry bias associated with solar heating is largest. In particular, stations using MODEM radiosondes have an increase of moisture during daytime but not during night-time. This is because MODEMs have a dry bias at low-levels during the day and a moist bias at mid-levels during night-time.

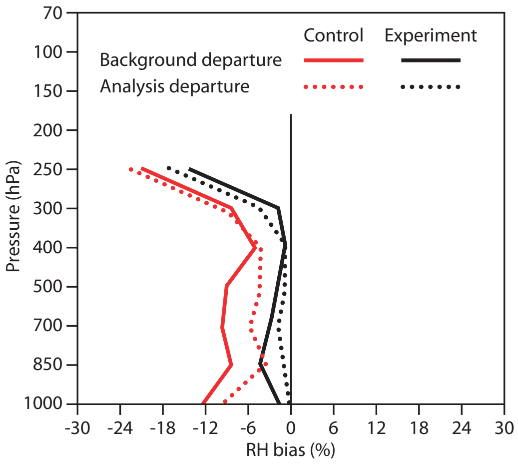
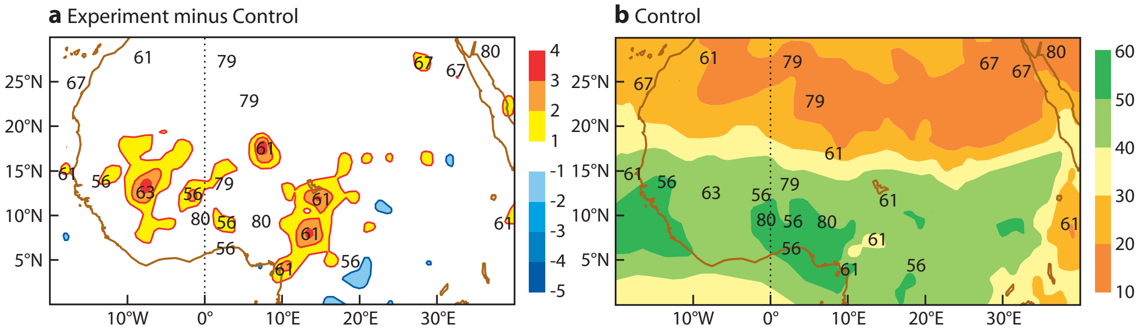


Figure 4 Bias of the relative humidity background departure (observations minus first guess, solid lines) and analysis departure (observations minus analysis, dotted lines) accumulated over July 2006 comparing the control experiment (red) and the radiosonde bias correction experiment (black) at Dakar radiosonde station (14.44°N, 17.30°W) using Vaisala RS80 radiosondes.


a Experiment minus Control

b Control

Figure 5 Mean total column water vapour (kg m^{-2}) from 14 to 23 July 2006 from analysis experiments: (a) Difference between radiosonde humidity bias correction experiment and control experiment at 12 UTC. (b) Control experiment at 12 UTC. Numbers depict the radiosonde type (61, 63 and 67 are Vaisala RS80; 79 and 80 are Vaisala RS92; 56 is MODEM; 49 is VIZ).

A significant impact is also found on simulated infra-red brightness temperatures from channel 10.8 µm derived from analysis fields from the two experiments (not shown). In the bias correction experiment there is an increase in cold cloud tops over the region of the Gulf of Guinea and Cameroon highlands, as well as an increase of lower-level clouds in the regions around N'Djamena (12.08°N, 15.02°E) and around Bamako (12.32°N and 7.57°E).

Figure 6 shows the impact on different diagnostics linked to convection for the model gridpoint nearest to Bamako. The humidity bias correction leads to a mean increase in Convective Available Potential Energy (CAPE) of 446.62 J kg^{-1} and a mean decrease in Convective Inhibition (CIN) of 25 J kg^{-1}. The impact of the humidity bias correction on CAPE and CIN is consistent with previous studies performed by correcting TOGA-COARE radiosonde data in the West Pacific warm pool.

In the areas around Bamako (12.32°N, 7.57°W) and N'Djamena (12.08°N, 15.02°E) there is also a precipitation increase of 2 mm/day in the short-range forecast (T+12 to T+36) in the bias correction experiment (not shown). Overall there is an increase in the precipitation over Sahel between 10°N and 15°N consistent with CAPE and CIN changes. However, the magnitude of the mean precipitation is still too low over this region in the forecast compared to the satellite-derived precipitation.

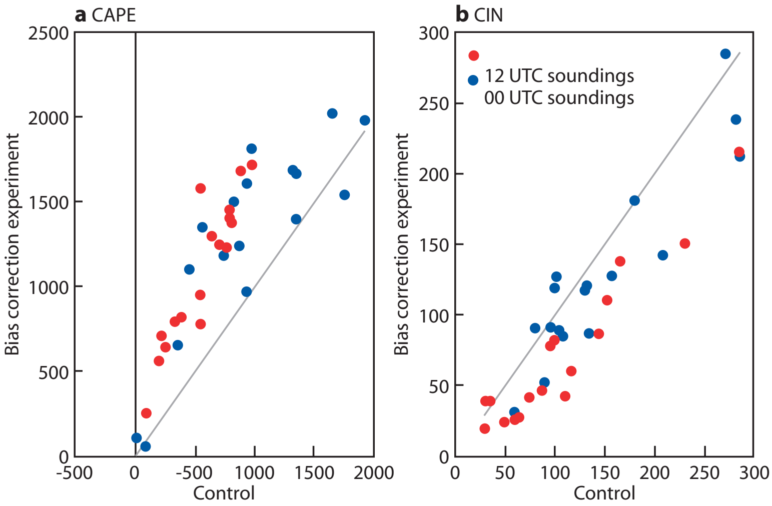


Figure 6 Scatterplots of (a) positive Convective Available Potential Energy (CAPE, J kg^{-1}) and (b) Convective Inhibition (CIN, J kg^{-1}) at Bamako (12.32°N, 7.57°W) from 2 to 18 July 2006 for the bias correction experiment versus the control experiment. Red dots depict 12 UTC soundings and blue dots 00 UTC soundings.

Evaluation of the medium-range forecast in West Africa

The onset of the West African monsoon is commonly defined as the shift in the band of precipitation and cloud associated with the ITCZ from the coast of Guinea (5°N) to around 10°N. This occurs sometime between end of June and beginning of July. Before the onset there is an intensification of the Saharan heat low at around 25°N and the establishment of the African Easterly Jet (AEJ) in the region around 15°N. Synoptic-scale African Easterly Waves (AEWs) develop through barotropic and baroclinic instabilities associated with the AEJ. The AEWs provide forcing for the development of Mesoscale Convective Systems. These four key components of the West African monsoon have been evaluated in the medium-range weather forecast using IFS cycles Cy30r1 (up to 11 September 2006) and Cy31r1 (from 12 September 2006) which were operational during the monsoon season in 2006. Forecasts at day 1 and day 5 illustrate the problems with the short-range and medium-range respectively. In IFS Cy30r1 and Cy31r1 the radiosonde humidity bias was not corrected.

Heat low

The heat low is the key driver to the advection of moisture inland by the low-level southwesterly monsoon flow just before the onset of the wet monsoon season. This results in the movement of the large-scale moisture and temperature gradient (also known as the intertropical front or ITF) to around 20°N. During the forecast the heat low tends to intensify, leading to a progressive strengthening of the monsoon low-level south-westerly flow in the forecast with respect to the analysis over land (north of 5°N) and a weakening over the ocean south of 5°N. As a result, the ITF tends to shift northwards (Figure 7). The gradient associated with the ITF is also weakened during the forecast as shown by the spreading of the 2-metre dew point temperature contours.

Intertropical Convergence Zone (ITCZ)

The mean precipitation band associated with the ITCZ in the short-range forecast during the peak of the monsoon season (August 2006) is located around 8°N whereas SYNOP stations indicate the maximum precipitation values are further north at around 12°N. This is confirmed by plotting a time series of an index for the latitude of the ITCZ for different forecast ranges. Figure 8 shows that the short-range forecast (e.g. day 1) is not able to shift the precipitation band from 5°N to 10°N during the monsoon onset. An apparent improvement with the forecast range (e.g. day 5) is due to the model drifting the ITCZ further north in association with the over-intensification of the heat low in the forecast.

African Easterly Jet (AEJ)

A simple index of the AEJ strength shows the decrease in the speed of the jet with forecast range (Figure 9). This is consistent with the weakening of the gradient associated with the ITF as shown in Figure 7.

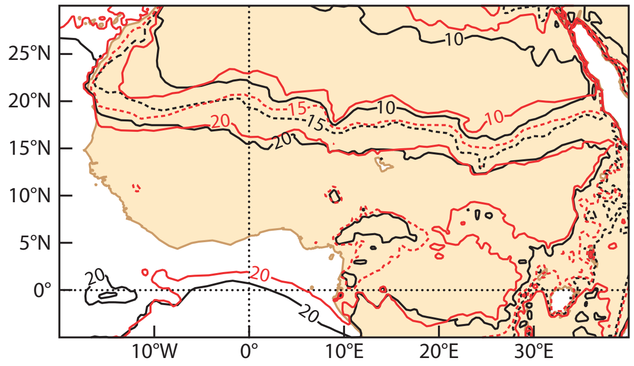


Figure 7 Mean 2-metre dew point temperature for August 2006 at 12 UTC from the analysis (black contours) and five-day forecast (red contours). Contours are plotted for 10°C, 15°C and 20°C to depict the intertropical front (ITF). Note that for forecasting purposes the location of the ITF is commonly defined by the 15°C contour (dash line).

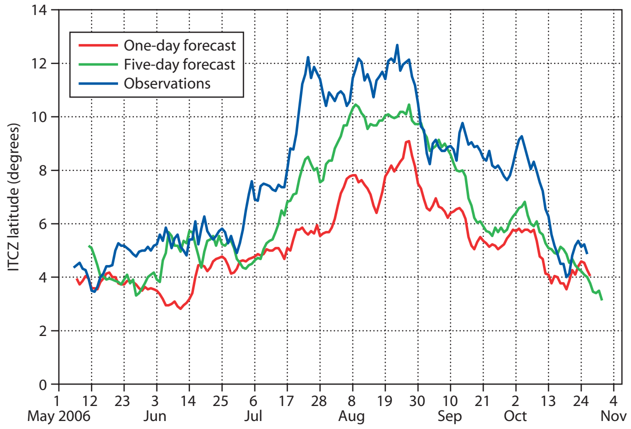


Figure 8 Time series of the ITCZ latitude computed as the latitude of the maximum zonally averaged precipitation between 10°W and 10°E for the one-day forecast, five-day forecast and observations based on the satellite estimated precipitation merged with raingauge data from the Famine Early Warning System (Courtesy of *CPC, NCEP, NOAA*).

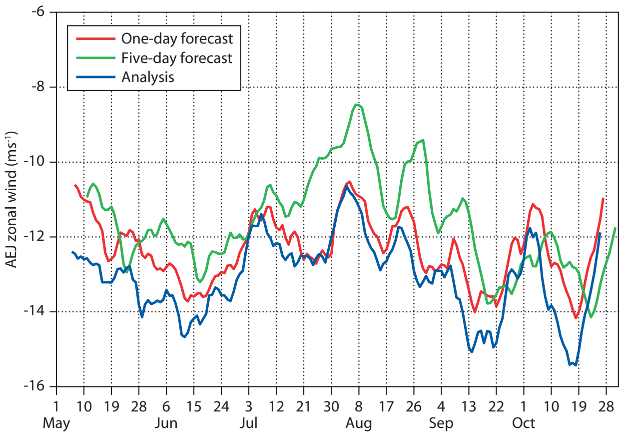


Figure 9 Time series of the zonal wind associated with the AEJ for the one-day forecast, five-day forecast and analysis. The AEJ zonal wind is computed as the maximum zonally averaged easterly zonal wind at 700 hPa between 10°W and 10°E.

African Easterly Waves (AEWs)

The AEWs have been evaluated in collaboration with the Met Office, Météo-France and NCEP (National Centers for Environmental Prediction) using diagnostics based on the curvature vorticity at 700 hPa. This effort has been coordinated by Gareth Berry and Chris Thorncroft from University of Albany. Curvature vorticity describes the vorticity associated with AEWs and shear vorticity that associated with the AEJ. Figure10 shows the propagation of the long-lived wave troughs as positive curvature vorticity anomalies in the operational ECMWF analysis. The analyses of the other meteorological centres compare well with the timing of wave troughs. The forecast accuracy with respect to analysis decreases rapidly at day 2 (Figure 11). The western region around 15°W has always a better forecast than the region around 15°E up to day 4. After day 3 the root mean square errors become as large as the magnitude of the 700 hPa curvature vorticity in the analysis, and thus, the forecast ceases to be useful. The rapid deterioration of the forecast of AEWs is probably linked to the lack of Mesoscale Convective Systems in the region during the forecast. These are very important in triggering the AEWs in the eastern region and modulating their lifecycle.

These errors reported in IFS Cy30r1 and Cy31r1 also affected the operational forecasts in 2007 with Cy32r2. However, a significant improvement occurred in the systematic error of the ITCZ location with cycle Cy32r3. This new cycle, which is currently operational, features an improved precipitation forecast in the short-range over the tropics (see *Bechtold et al.,* 2008) and in particular over West Africa where the mean precipitation band associated with the ITCZ is shifted northward by approximately 1 degree.

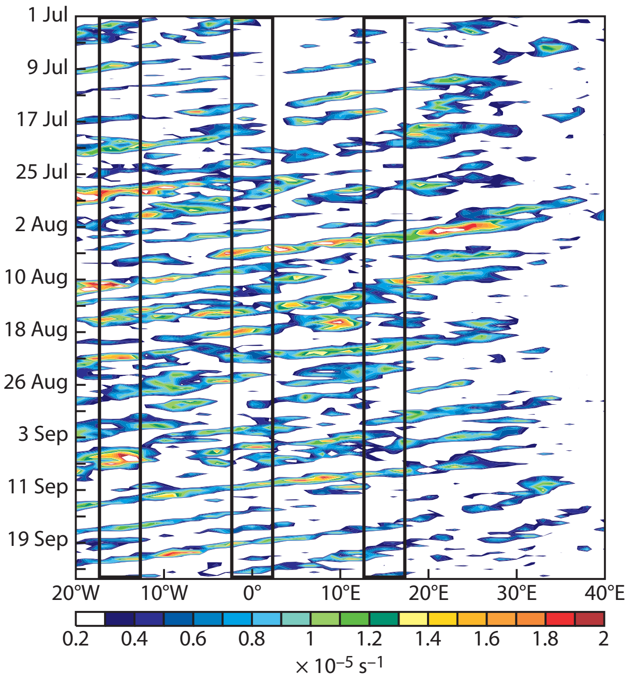


Figure 10 Hovmöller longitude-time diagram of curvature vorticity at 700 hPa from analyses averaged within a band between 5°N to 15°N showing synoptic African easterly wave activity from 1 July to 25 September 2007. For clarity only positive values are shown which depict the trough of the waves. The boxes around 15°W, 0°E and 15°E with a 5° width depict the different longitude bands for which the RMS error has been computed in Figure 11.

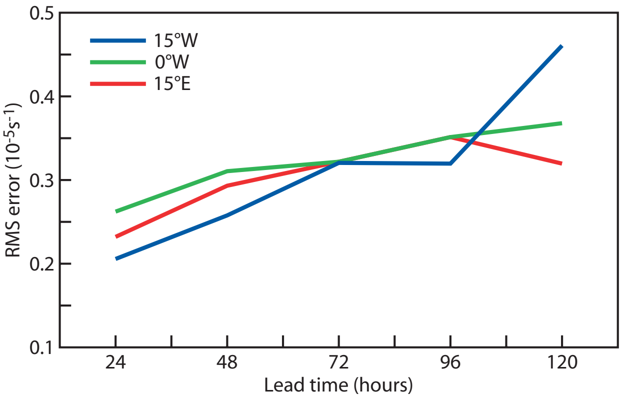


Figure 11 Root mean square errors of 700 hPa curvature vorticity from forecast at different ranges with respect to analysis for the three boxes indicated in Figure 10.

The AMMA reanalysis

The AMMA project has dedicated a large effort to enhance the West African radiosonde network in 2006 with special observing periods (SOPs) covering the different phases of the wet monsoon. This effort has been hampered by persistent communication problems, which resulted in valuable radiosonde data not reaching the GTS. Consequently this missing data was not included in the operational analysis at ECMWF as well as other operational centres. Even the data that reached the GTS very often contained many missing values due to problems encountered during the automatic encoding process. In addition to radiosonde data, many dropsondes were deployed from research aircrafts and gondolas during the SOPs which could not be used in the analysis either. Therefore, it was recognised by the AMMA community that a special AMMA reanalysis was necessary to include this unique dataset in a region which generally suffers from data scarcity.

Another advantage of performing a reanalysis is the availability of a new IFS cycle (Cy32r3) with improved physics and a new radiosonde temperature and humidity bias correction scheme (see *Bechtold et al.,* 2008). Given the improvement to the systematic error that affects the short-range precipitation forecast over West Africa, Cy32r3 is particularly well-suited for the AMMA reanalysis. The reanalysis is currently running with T511 resolution and 91 vertical levels and it will span the wet monsoon period from 1 May to 30 September 2006. The humidity radiosonde bias correction developed for the AMMA radiosonde data described earlier in this article is also applied to the reanalysis.

In the reanalysis all the sounding data collected in the AMMA database are used. Details are given in Box A.

In order to test the impact of the extra AMMA soundings, a control experiment will be run with a data-poor scenario for the month of August (i.e. the month with more observations) using the same IFS cycle and resolution as the AMMA reanalysis. In this control experiment, only the radiosonde stations that were reporting reliably in 2005 will be used (i.e. pre-AMMA scenario).

Sounding data collected in the AMMA database

A

The sounding data collected in the AMMA database includes:

- 6,063 high resolution radiosondes/dropsondes collected from 21 stations, 3 research vessels and 2 research aircrafts. These have been thinned from about 2,500 to approximately 300 vertical levels.
- Radiosondes launched from operational stations, research stations and research vessels obtained via the GTS. The radiosonde data from West Africa typically contains 70 to 100 levels. These data are only used when there is no corresponding high-resolution data available.
- 101 dropsondes from research aircrafts obtained via the GTS.
- 110 dropsondes from gondolas, also known as driftsondes.
- 7,317 pilot balloons that only measure wind profiles obtained via the GTS.

The development and deployment of the driftsonde system was a collaborative effort between the Earth Observing Laboratory (EOL/NCAR) and the French Space Agency (CNES) as part of the SOP3 period to investigate the development of tropical cyclogenesis downstream of Africa. It is the first time they will be assimilated in an analysis experiment. Preliminary comparisons with operational analysis show a good agreement.

doi:10.21957/28vtm6dpt6

Summary of progress, further activities and plans for the future

Evaluation of the short-range forecast shows a systematic error in the location of the main precipitation band associated with the ITCZ over continental West Africa by approximately 4° to the south during the wet monsoon period. An improvement of this systematic error has been detected with the changes in the vertical diffusion, convection parameterizations, hydrology as well as the radiosonde humidity bias correction introduced in IFS Cy32r3. This has been further improved by developing a refined radiosonde humidity bias correction for the West Africa region which takes into account the variation of the radiosonde humidity bias with the observed humidity.

Results from analysis experiments show how the correction of radiosonde humidity bias is particularly important in the West African region due to its impact on the development of convection. This new radiosonde humidity bias correction for the AMMA region is applied using IFS Cy32r3 in the AMMA reanalysis for the 2006 West African wet monsoon season during the AMMA observational campaign. This is expected to benefit a wide number of AMMA-related studies that make use of the reanalysis, in particular those focusing on the water cycle.

Another important advance for the West African region is the development of new seasonal products at ECMWF. These products provide information on probability distribution of rainfall and near surface temperature anomalies over the West African region. PRESAO, a Regional Climate Outlook Forum activity dedicated to West Africa and coordinated by ACMAD, makes regular use of those products. Monsoon indices, based on the large-scale distribution of observed rainfall anomalies, have been recently developed for both the West African and South Asian regions. The forecast skill of those indices has been estimated by looking at the seasonal forecast performance in the past 25 years and is available on the web at: www.ecmwf.int/products/forecasts/d/charts/seasonal/forecast/seasonal_range_forecast/group

Although model errors affect the rainfall variability over the tropical lands, with the monsoon indices the predictive skill over land can be improved by exploiting teleconnections with adjacent ocean regions.

Despite significant improvements in the systematic error of precipitation over West Africa, there is still a lack of convection over the Sahel in the model. Comparison of high-resolution radiosonde data and model analysis/forecast at Niamey (Niger) show significant differences in the boundary layer moisture distribution which are likely due to the mixing being too strong in the model boundary layer. This issue is currently being investigated by the Physical Aspects Section at ECMWF. Other ongoing work to improve the medium-range and seasonal forecasts also includes the use of a better representation of land surface initial conditions, specially in terms of soil moisture obtained from off-line land surface models using observed precipitation and radiation forcing and from remote sensing (see the news item about the SMOS project on page 5 of this edition of the *ECMWF Newsletter*). In addition it is expected that the assimilation of more satellite data (e.g. TRMM or SSM/I microwave brightness temperatures sensitive to clouds and precipitation) might improve the quality of moisture analyses and precipitation forecasts.

The success of the work done at ECMWF on the AMMA project strongly relies on external collaboration with many AMMA partners.

- Collaboration with Jean-Blaise Ngamini from ASECNA, Doug Parker from University of Leeds and Adreas Fink from University of Cologne on the radiosonde monitoring has been invaluable.
- The visit of André Kamga from ACMAD in 2006 provided advice on model evaluation and the development of forecast products for West Africa.
- The development of the AMMA radiosonde bias correction and model evaluation has benefited from discussions and exchange of diagnostics, data and information with Mathieu Nuret, Françoise Guichard and Jean-Philippe Lafore from Météo-France.
- The verification of the AMMA radiosonde humidity bias correction method performed in the reanalysis is currently in progress using GPS which provides a fully independent observational dataset of TCWV. The comparison of GPS/model TCWV is being performed by Olivier Bock from IPSL.
- Collaboration with Dave Parsons, Junghong Wang and Kate Young from NCAR on the use of driftsonde data has also made possible the use of a new type of dataset in the AMMA reanalysis.

The commitment and expertise of the wide variety of collaborators has helped ensure the success of the project. Also this collaboration has laid the foundation for further developments which will bring benefits to the people of West Africa and the wider meteorological community.

Further Reading

Bechtold, P., M. Köhler, T. Jung, M. Leutbecher, M. Rodwell & **F. Vitart,** 2008: Advances in simulating atmospheric variability with IFS cycle 32r3. *ECMWF Newsletter No. 114,* 29–38.

Bock, O., M.-N. Bouin, A. Walpersdorf, J.-P. Lafore, S. Janicot, F. Guichard & **A. Agustí-Panareda,** 2007: Comparison of ground-based GPS precipitable water vapour to independent observations and NWP model reanalyses over Africa. *Q. J. R. Meteorol. Soc.,* **133,** 2022–2027.

Lorenc, A.C., D. Barker, R.S. Bell, B. Macpherson & **A.J. Maycock,** 1996: On the use of radiosonde humidity observations in mid-latitude NWP. *Meteorol. Atmos. Phys.,* **60,** 3–17.

Parker, D.J., A. Fink, S. Janicot, J.-B. Ngamini, M. Douglas, E. Afiesimama, A. Agustí-Panareda, A. Beljaars, F. Dide, A. Diedhiou, T. Lebel, J. Polcher, J.-L. Redelsperger, C. Thorncroft & **G.A. Wilson,** 2008: The AMMA radiosonde programme and its implications for the future of atmospheric monitoring over Africa. *Bull. Am. Meteorol. Soc.* (in press).

Redelsperger, J.-L., C.D. Thorncroft, A. Diedhiou, T. Lebel, D.J. Parker & **J. Polcher,** 2006: African Monsoon Multidisciplinary Analysis: An international research project and field campaign. *Bull. Am. Meteorol. Soc.* **87,** 1739–1746.

Wang, J., H.L., Cole, D.J. Carlson, E.R. Miller & **K. Beierle,** 2002: Corrections of humidity measurement error from the Vaisala RS80 radiosonde – application to TOGA-COARE data. *J. Atmos. Oceanic Technol.,* **19,** 981–1002.

European Centre for Medium-Range Weather Forecasts, Shinfield Park, Reading, RG2 9AX, England

doi:10.21957/28vtm6dpt6