

West African monsoon 2012

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West African Monsoon 2012

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Introduction

Living up to its reputation as a highly variable climate system, the West African Monsoon (WAM) in 2012 contrasted strikingly with that of the previous year, when it was delayed, patchy, and irregular. In 2012, it was extremely wet in many areas, although the Guinea coastal countries and some crucial agricultural regions (such as southwest Niger) retained very dry conditions that persisted from 2011. The region experienced its third biggest food crisis in the last seven years, this time triggered by severe flooding following on from the drought in 2011, and previously the floods in 2010. Successive years of significant hydrological events (Figure 1) in western Africa (for example, deficient rainfall in 1972–1973 and 1982–1984, excessive rainfall (2012), and alternating extreme years such as 2011–2012) have far-reaching humanitarian impacts that include lack of water, energy, pasture and food, and famine, loss of life, livestock, and property, and mass migration and environmental refugees. This article reviews the backdrop to the 2012 WAM, the seasonal forecast, monsoon evolution and ongoing socio-economic implications for the region.

Background

Typically, the onset of the WAM coincides with the establishment and development of a cold tongue of water in the Gulf of Guinea in mid-April, resulting from atmospheric forcing in this area and oceanic processes (Brandt *et al.*, 2011; Coëtlogon *et al.*, 2010; Vellinga *et al.*, 2012). This enhances the meridional temperature gradient between the ocean and the continent, and rain is concentrated over the Guinean Coast (5°N) between mid-April and the end of June. As the sun migrates polewards during the boreal summer, the land warms faster than the ocean, enhancing the thermal and moisture contrasts between the Guinea coast

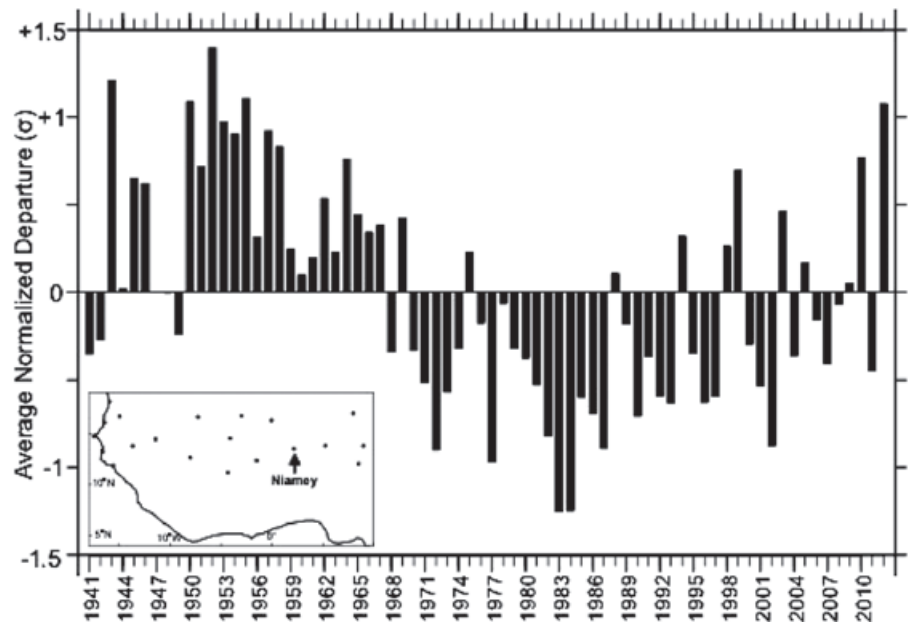


Figure 1. Time series (1941–2012) of average normalized April to October rainfall departure (σ) for 20 stations in the west African Sudano-Sahelian zone (11°–18°N) west of 10°E. Normalization is with respect to 1941–2000. Station locations are shown in inset map, where arrow indicates location of Niamey station treated in Figure 3. Source: Boyd *et al.* (2013).

and the tropical Atlantic to the west. This drives the surface pressure pattern of a Saharan ‘heat low’ between the Atlas and Hoggar heights in mid-June (Lavaysse *et al.*, 2009). Typically, the rain belt moves abruptly north to the Sahel (11°N), as the low-level moist southwesterly flow is diverted inland between the Atlantic cold tongue and the Saharan heat low (Peyrillé *et al.*, 2007; Thorncroft *et al.*, 2011) and pushes back the dry, northeasterly trade winds (known locally as the Harmattan winds) crossing the African continent. This abrupt northward shift of the monsoon at its ‘onset’ time corresponds to a 10–15 day transition in the WAM seasonal evolution, and its mean date of occurrence varies depending on the variable used. Over the last 40 years, the climatological date for this large-scale shift (‘monsoon jump’) has been between 24 and 30 June with an observed standard deviation of 8 days (Janicot *et al.*, 2010). Local small-scale variations in the distribution of rainfall, superimposed on this large-scale Sahelian monsoon onset, can be substantial. The abrupt northward shift of the

monsoon at its onset time contrasts with its relatively smooth retreat, followed by a second rainy season over the Guinean Coast, from October to November.

Socio-economic backdrop to the 2012 West African Monsoon

Prolonged dry spells and erratic rains in 2011 resulted in food production in western sub-Saharan Africa falling by a devastating 34%. As the west African rainy season drew to its close with a relatively rapid southward retreat of the rain belt (Cornforth, 2012; Figure 6), the humanitarian impact was significant with many areas across the Sahel experiencing water and food shortages. By early 2012, one-third (5.4 million) of Niger’s population was in a ‘food-insecure’ state (World Food Programme Report, January 2012).

As the 2012 rainy season evolved, 18.7 million people were facing high food-insecurity with more than a million children under the age of five at risk of severe acute

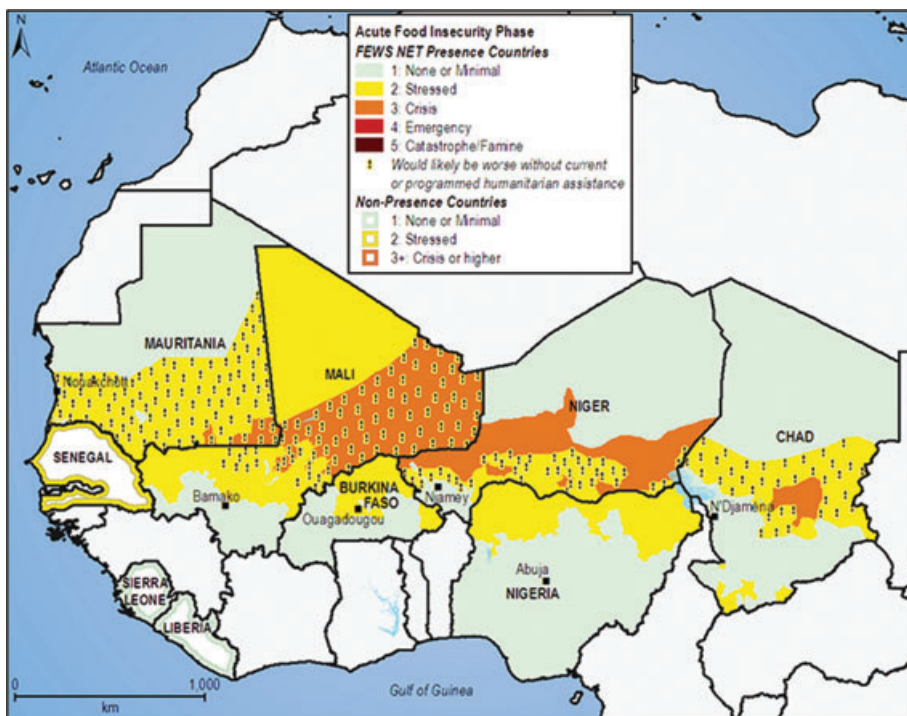


Figure 2. Map of most likely food security outcomes, July to September 2012. Source: FEWS NET (2012a).

malnutrition (FEWS NET, 2012a; Figure 2). The situation was critical in parts of Burkina Faso, western Niger, and in central Mali where 1.6 million people were already in severe need (FEWS NET, 2012d), and it was exacerbated by civil insecurity and conflict in Nigeria, Mali, Sudan and south Sudan. An emergency response was required to protect lives and livelihoods (FAO, 2012a), prompting the international non-governmental organizations (NGOs) to launch a high profile media campaign in early July (Economist, 2012).

Given this background, accurate seasonal forecasts and monsoon-onset forecasts were vital to help the farming communities make timely decisions, such as ensuring planting was coincident with the beginning of the rains.

Forecast of the 2012 WAM

The WAM seasonal forecasts are generally prepared in May/June by the World Meteorological Organization (WMO) designated Global Producing Centres (GPCs). The different model outputs are then submitted to the annual West African Regional Climate Outlook Forum (RCOF; Ogallo *et al.*, 2008; Kadi, 2012), known as PRESAO. National and international representatives from the GPCs then gather together at the PRESAO to issue a consensus forecast, contributing further climate analyses based on the observed regional climate circulation anomalies and an evaluation of important influences such as the El Niño/La Niña-Southern Oscillation (ENSO) and the tropical Atlantic dipole. The 15th PRESAO was held in May 2012 in Ouagadougou, Burkina Faso.

Meteorological situation prior to the expected (climatological) WAM onset in mid-June

In early April 2012, the end of the weak-to-moderate strength La Niña of 2011–2012 resulted in ocean temperatures and atmospheric circulation anomalies returning to levels consistent with neutral ENSO conditions (WMO El Niño/La Niña Update, May 2012). In this neutral state, ENSO is not normally a dominant player in the WAM. This situation continued through June, with forecast models and expert opinion suggesting that SST anomalies were likely to oscillate around neutral conditions into the 2012 monsoon season. Beyond July 2012 there was considerable uncertainty, with around half of the dynamical climate models surveyed predicting the development of El Niño during July to September and half predicting neutral conditions.

Equatorial Atlantic Ocean sea-surface temperatures (SSTs) and the inter-hemispheric contrast in SST gradients (Lamb and Pepler, 1992; Hoerling *et al.*, 2006; Losada *et al.*, 2010) are also known to be associated with Sahel rainfall. In May 2012 the inter-hemispheric contrast between the north Atlantic/north Pacific and the south Atlantic/Indian Oceans was weak, suggesting little influence on rainfall. In the tropical Atlantic, SSTs were near to, or slightly below, average, but they were above average in both northern and southern extra-tropical regions. However as the onset date approached, the anomalies appeared to shift southwards with the greatest negative anomalies in the Gulf of Guinea and positive

anomalies transferring southwards in the north Atlantic.

Consensus seasonal forecast

Figure 3(a) shows the twelve GPC forecasts (ensemble mean) for the June–July–August (JJA) rainfall that were available in time for the 2012 PRESAO. Several of these (including GloSea4 (Met Office Global Seasonal model v4) 1996–2009, the ECMWF (ECMWF System 4 Reading, UK) 1981–2010 15 member ensemble, and the Meteo-France (Arpège model) 11-member ensemble 1981–2010) were combined to produce the EUROSIP multi-model ensemble mean forecast provided for the 15th PRESAO RCOF in May 2012 (Figure 3(b)).

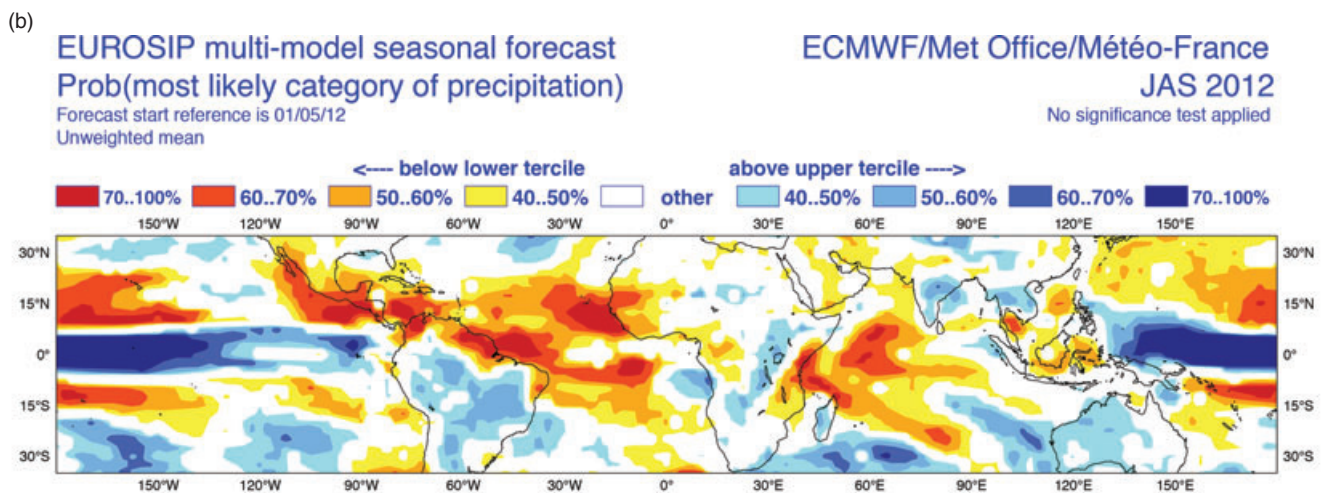
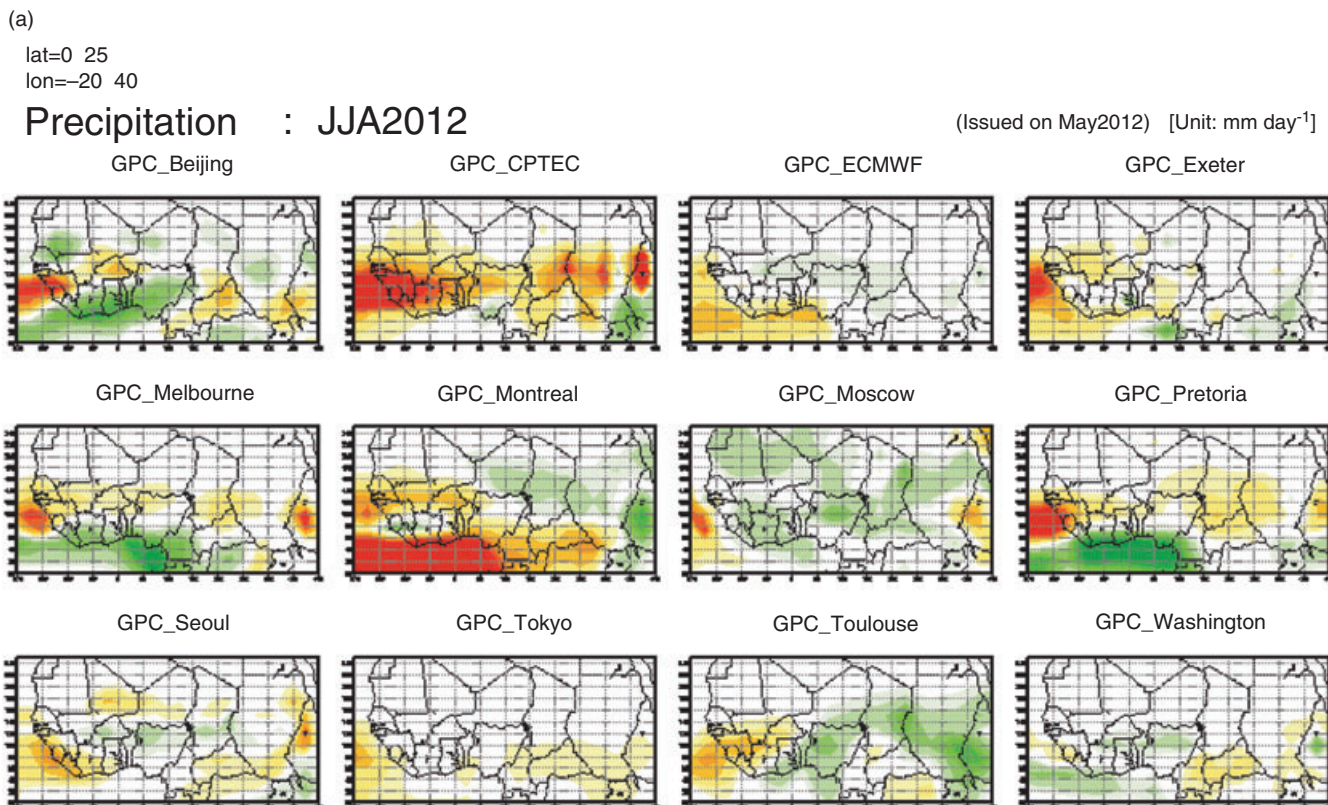
Given the weak tropical SST patterns and ENSO neutral condition, the EUROSIP forecast favoured below average rainfall in the northwest of the region and above average rainfall for a limited number of grid boxes elsewhere; otherwise the forecast was based on climatology. This compares with the PRESAO 2012 consensus seasonal forecast shown in Figure 4. The numbers for each zone indicate the probability of rainfall in each of the three categories: above, near, and below normal as defined by terciles.

1. Above normal rainfall was 'very likely' (Zone II) over the eastern Sahel around Lake Chad in Niger, and over northeastern Nigeria and much of Chad.
2. Below normal to normal precipitation was 'very likely' (Zone I) over the western Sahel in the northern half of Senegal, southern Mali and southern Mauritania.
3. Above normal to normal precipitation was 'very likely' (Zone III) over much of Burkina Faso and northern parts of Togo, Benin and Ghana.
4. Normal precipitation was 'very likely' (Zone IV) along the west African coast from Liberia to Nigeria and much of southern Cameroon.
5. The forecast was based on climatology (33%/33%/33%) elsewhere.

Regarding the onset, analysis of a number of new experimental products (Vellinga *et al.*, 2012) indicated no overall clear signal for the 2012 WAM. Locally, however, a normal-to-late onset was suggested to be more likely over northern Senegal, southeastern Mauritania, western Mali and the Gambia, whereas in parts of the central/eastern Sahel (Niger and western Chad) a normal-to-early onset was considered the most likely outcome.

Evolution of the 2012 WAM

Despite the weak global SST anomaly patterns, the WAM turned out to be anomalously wet in 2012, although prolonged drought prevailed for countries lying along the Guinea coast.



Forecast issue date: 15/05/2012



Figure 3. (a) 12 Global Producing Centre (GPC) forecasts (ensemble mean) for the June-July-August (JJA) rainfall available at the 2012 PRESAO (Source: Richard Graham, UKMO); (b) EUROSIP ensemble mean forecast for July-August-September 2012 rainfall, showing the probability of exceeding median rainfall (Source: Laura Ferranti, ECMWF). Yellow to red shading indicates a forecast of below-normal rainfall, greens and blues above-normal rainfall.

The rainfall across the region mostly results from the northward movement of the low-level monsoon flux from March to August and its southward retreat during September to November. At its northernmost reach, the humid air masses meet drier and warmer air to form the Inter Tropical Front (ITF). Since the rains appear to the south of the ITF, tracking this through the season enables a quick first evaluation of the progress and quality of the rainy season,

although this relationship between the ITF and seasonal rainfall is strong only early and late in the WAM season (Lele and Lamb, 2010). Time series illustrate the mean latitudinal values of the western (Figure 5(a)) and eastern (Figure 5(b)) segments of the ITF and their respective evolutions from April to October 2012. Clearly the ITF exhibited several above-average northerly positions throughout the year, including at the start of the season. As a result, early-onset

conditions with above average rainfall prevailed across much of the region with the ITF positioned north of its average decadal position during late May and early June in both the western and eastern regions of sub-Saharan Africa. In Senegal, the Senegalese National Agency for Civil Aviation and Meteorology (ANACIM) reported that the first rain was recorded on 19 June, with a maximum on 29 June: *we got it pretty well in our forecast as stated to*

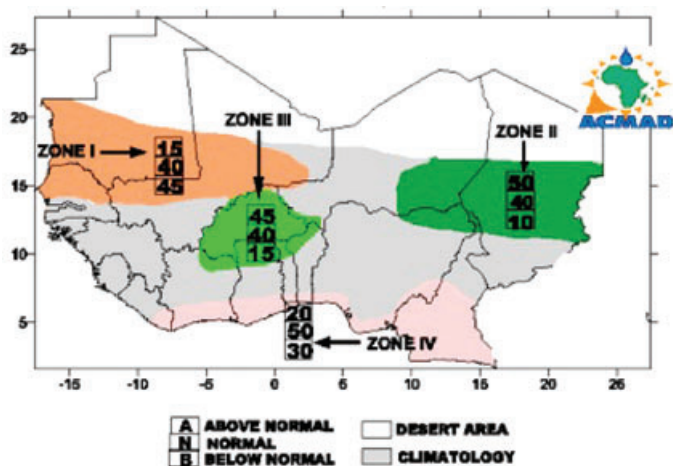


Figure 4. Consensus forecast for July-August-September rainfall in 2012. Boxes indicate likelihood of above-normal (top), normal (middle), below-normal (bottom) and climatological (grey) rainfall. Climatology zones represent homogeneous climatic rainfall.

farmers during the (Early Warning-Early Action) workshop between 18 and 26 June (pers comm, Ousmane Ndiaye, ANACIM).

Above normal temperatures over north Africa and the Mediterranean Sea were a dominant feature from May to July 2012 (and beyond). The high temperatures, combined with rainfall recorded anomalously north of the Sahel over desert locust prone areas, led to the mobilization of international support to strengthen locust development monitoring. Significant dust, lifted from the Sahara Desert was observed by NASA as it traversed the Atlantic, reaching the Florida coast during July (Figure 6(a)), and dry riverbed sediments from the Sudan desert were blown across the Red Sea during the following week (Figure 6(b)). The Saharan dust also fell in rain over parts of the United Kingdom on 28 June (Met Office, 2012; J. Galvin, pers. comm., 2012).

From late July to late August 2012, rainfall in excess of 150% of normal totals was recorded in southeast Mauritania and

adjacent areas in Mali, through the middle and lower Niger river basin in Mali, Niger, Nigeria and Cameroon, and the Lake Chad basin in Niger, Chad, Nigeria and Cameroon. Flash and riverine floods occurred upstream of many locations of the Lake Chad and River Niger basin. The worst southern Niger flooding in more than 80 years resulted from heavy rainfall (more than 150% of average in August and September, Figure 7(a)), driving more than 500 000 people from their homes, killing dozens, and flooding nearly 10 000 hectares of ricefields in the Niger River valley (FEWS NET, 2012c, 2012e). The flooding in a neighbourhood of Niamey (Niger) on 19 August is shown in Figure 7(b), as the River Niger broke its banks following a significant storm the previous day.

Further west, torrential rain destroyed homes, displaced several hundred people, and flooded farmlands. Dakar, the capital of Senegal, recorded 161mm on 26 August, and the government called for an immediate emergency and contingency plan as

more than 11 400 homes were damaged and nearly 287 000 residents displaced. In Nigeria many areas were devastated by severe flooding, with many people drowned, injured and missing. In northeastern, Nigeria, more than 126 settlements were submerged in the riverine areas, displacing several families with many missing despite the Cameroon authorities issuing notices about the impending release of water from the Lagdo Dam.

Above average rainfall also prevailed across east-central Africa during the first week of August producing localized flooding and causing the displacement of at least 15 000 people throughout Sudan, and hitting refugee camps in Darfur and bordering Chad. By early August at least 1000 families in eastern Sudan and 14 000 people in the far-west region of Darfur had been affected (FEWS NET, 2012b).

Nearly a month of heavy rain in September destroyed homes and farms and killed livestock throughout the region. Flood conditions stretched from Senegal eastwards to Chad, with heavy rainfall in west and central Africa (Relief Web, 2012), especially in Nigeria, Niger, Chad and Senegal. Torrential rains produced deadly flooding in Nigeria and necessitated the release of water from the Jebba and Kainji hydropower dams on the Niger river in late September to prevent their collapse. Hundreds of acres of fields, gardens, mosques and drinking-water wells were engulfed by water according to the local Red Cross and the UN. One report stated: *the meteorological people have been giving some warnings, but those warnings hardly get down to people in villages... the government needs to put in place 'permanent infrastructure' and 'align water channels' to avert a re-occurrence* (<http://www.businessweek.com/news/2012-09-27/nigerian-in-flood-emergency-as-farms-roads-submerged>) though the government was keen

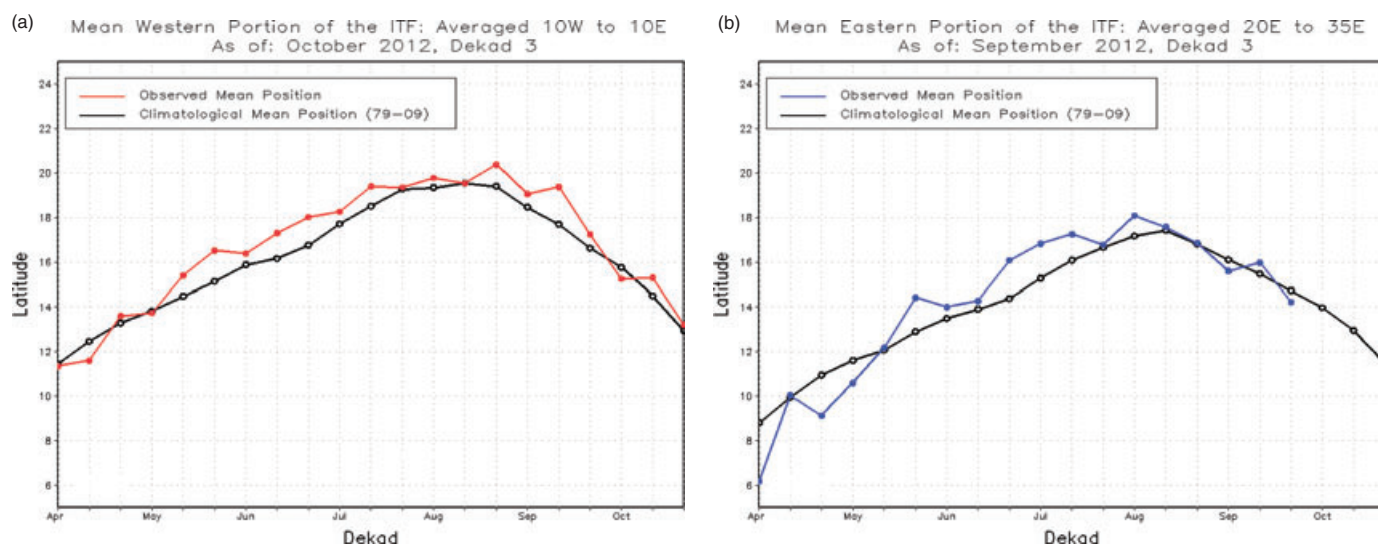


Figure 5. Time series of the evolution of the latitudinal means of the western (a) and eastern (b) portions of the Inter Tropical Front (ITF). Source: NOAA Climate Prediction Desk.

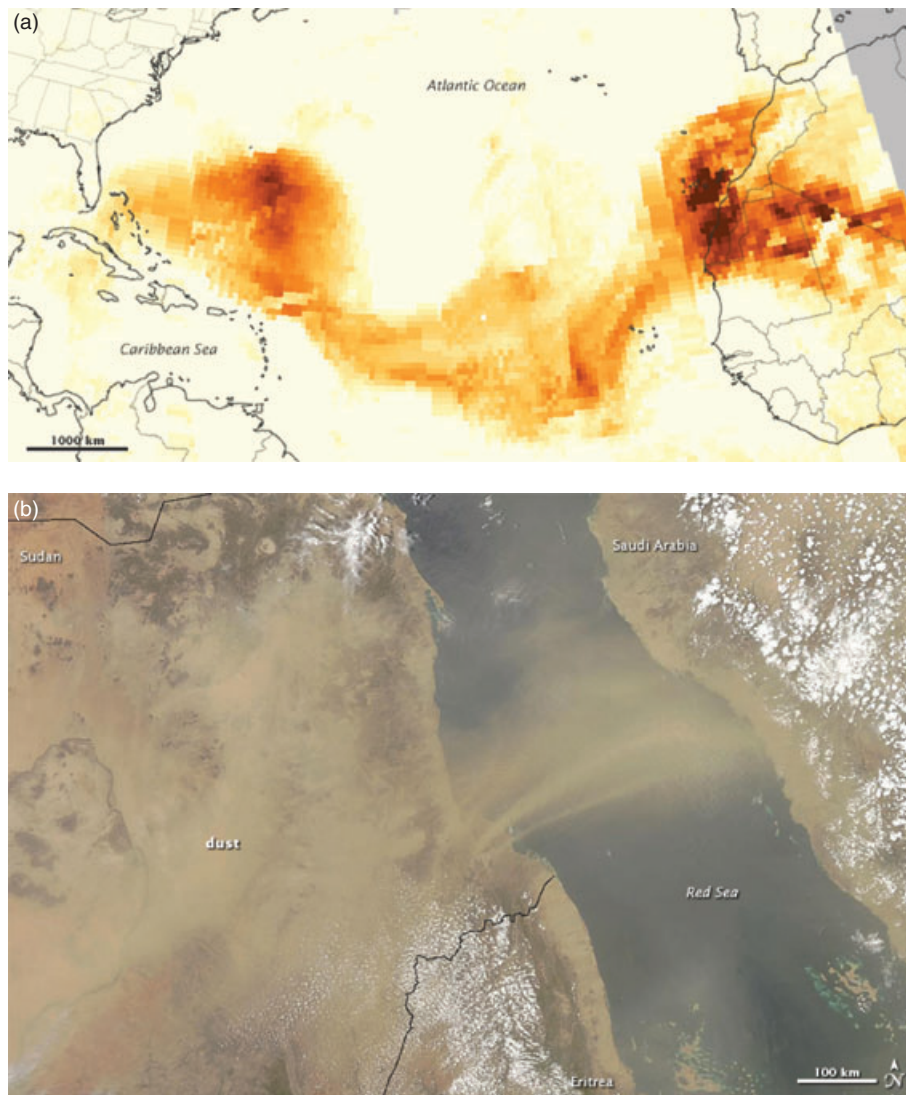


Figure 6. (a) Dust plume crossing Atlantic Ocean on 21 July 2012. This colour-coded map uses data collected by the Ozone Mapper Profile Suite on the Suomi National Polar-orbiting partnership satellite. The greater concentrations appear in dark orange-brown. Source: NASA Earth Observatory; (b) Dust plume crossing Red Sea on 26 July 2012. This is a MODIS natural-colour image from NASA's Aqua satellite. Source: NASA Earth Observatory.

to stress the need for individuals to move away from flood plains.

In Niger, floods resulted in 88 deaths, the loss of over 24 000 homes, and affected over 51 000 people during September. Morocco provided nearly 45 tonnes in foodstuff as part of its humanitarian aid to Niger in early October. In Chad, flooding destroyed over 94 000 homes in September, while 630 000 acres of cropland and nearly 520 000 people were adversely impacted. As the active 2012 season drew to a close, a devastating humanitarian crisis in west and central Africa was apparent. Figure 8 summarizes the flood situation as it stood in mid-October, according to the UN Office for the Coordination of Humanitarian Affairs (<http://reliefweb.int/map/nigeria/west-and-central-africa-floods-situation-15-oct-2012>). October continued to bring heavy rain to Nigeria, Niger, Chad and Cameroon. As a result of these unusually heavy rains and the ecological conditions, two generations

of locust breeding occurred. The end of the rains, with the vegetation drying out, raised many concerns as this caused the locusts to concentrate and group in those areas that were still green in the Sahel, especially northeast Mali, northern and central Niger and northeastern Chad, with swarms forming during the remainder of October and in November, destroying fragile harvests (FAO, 2012b).

Throughout the monsoon period the lack of rain in the southern areas, predominantly around the Guinea coast, made for a stark contrast with the regions of flooding. The below-average rainfall resulted in extremely dry pasture lands and poor harvests, and served as a factor in worsening the hunger crisis within those countries (<http://www.bbc.co.uk/news/world-africa-19074859>), perpetuated since 2011. Humanitarian relief efforts (<http://www.wfp.org/stories/sahel-crisis-by-country>) were deployed to address famine and poor living conditions for the

7.7 million people estimated to be affected (FAO/WFP, November 2012).

Analysis and verification

The anomalously wet 2012 WAM season is likely to have been linked to the convective phase of a non-dispersive Madden–Julian oscillation, strong African Easterly Wave (AEW) activity, and an ENSO in its transition phase towards El Niño. ENSO-neutral conditions continued through the WAM season. Although SST anomalies in the tropical eastern equatorial Pacific did increase as a result of weak El Niño levels over the monsoon period, (http://www.wmo.ch/pages/prog/wcp/wcasp/enso_update_latest.html), overall conditions remained neutral because the overlying atmosphere failed to respond (i.e., sea level pressure, wind and cloud patterns were near normal).

Although there was not a significant change in the global SST pattern, active phases of the Madden–Julian oscillation (MJO, see e.g. Zhang, 2005; Lavender and Matthews, 2009; Janicot *et al.*, 2010) reached Africa during the last two weeks of June, and again in August. Its regional effects can include a stronger than normal African Easterly Jet (AEJ), favourable for the generation and development of African Easterly Waves (AEW), frequent development of deep convective clouds with moderate to heavy precipitation, and strong interactions between precipitating events and subtropical features over the Mediterranean region.

AEWs are key synoptic features of the WAM and are important for distributing rainfall geographically and temporally. The 2012 AEW activity is shown in Figure 9(a) as indicated by the positive 2–10 day filtered Eddy Kinetic Energy (EKE). When AEW activity was anomalously high during mid-to-late June, the convectively active phases of the MJO and a convectively-coupled atmospheric Kelvin wave (CCKW, Schreck and Molinari, 2011) were both located at the longitude of west Africa, resulting in stronger westerly wind anomalies (Figure 9(b)). These may have contributed to the earlier than expected onset of the WAM. The period of low AEW activity that followed at the beginning of July was probably associated with the convectively-suppressed phases of the MJO. AEW activity reinvigorated however around 18 July (Figure 9(a)) over the Eastern Highlands in association with the passage of another Kelvin wave (Mounier *et al.*, 2007). Strong, spatially-coherent westerly wind anomalies continued across the tropical Atlantic and western Africa in association with the enhanced MJO activity throughout the monsoon period.

Given these highly active sub-seasonal variability patterns, observed rainfall was mostly above average north of 10°N, and below average further south near the

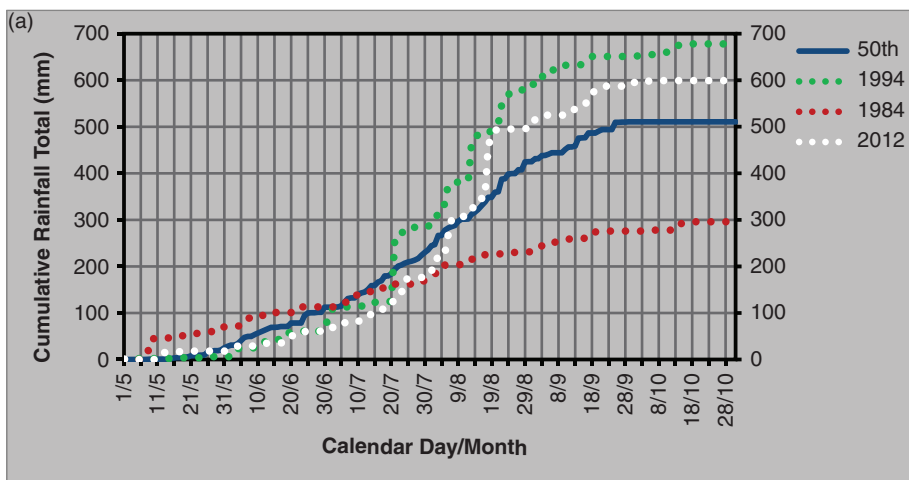


Figure 7. (a) Rainwatch cumulative precipitation (white line) depiction for Niamey (Niger) 2012, showing the WAM and comparing the season with the infamous 1984 drought year (dark red line), very wet 1994 (green line), and historical median (blue line). Abscissa is labelled in day/month. (Source: Rainwatch 2012: Peter Lamb, Aondover Tarhule and Issa Lélé, Cooperative Institute of Mesoscale Meteorology, University of Oklahoma). (b) Flooding in a neighbourhood of Niamey (Niger) on 19 August 2012 as the River Niger breaks its banks (Source: Plan International.)

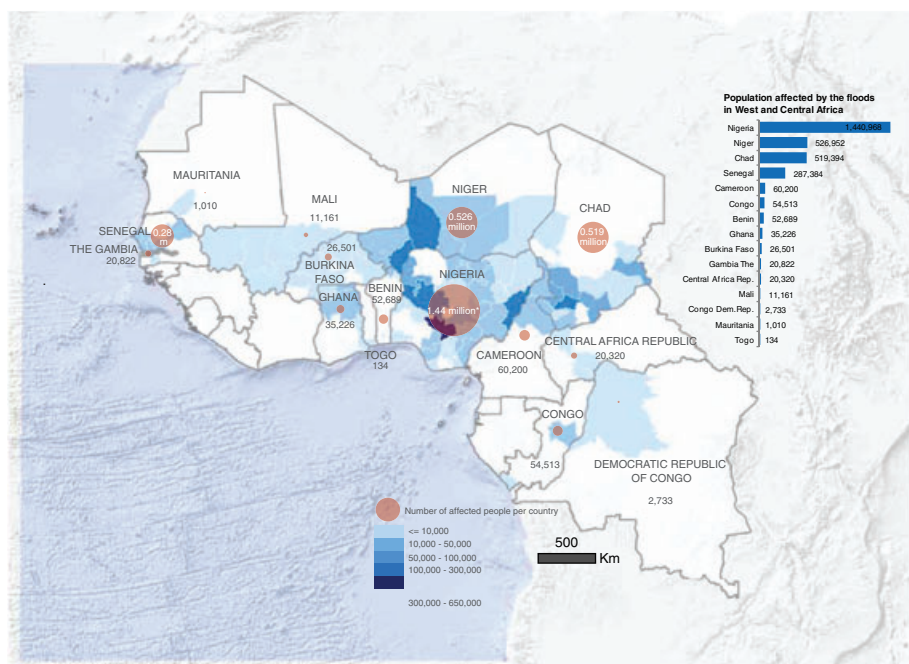


Figure 8. Overview of west and central Africa flood situation on 15 October 2012. Source: UN Office for the Coordination of Humanitarian Affairs (<http://reliefweb.int/map/nigeria/west-and-central-africa-floods-situation-15-oct-2012>).

Guinea coast, according to two datasets, TRMM (Figure 10(a)) and CPC-FEWS, (Figure 10(b)). Comparing the tercile verification plots from TRMM (Figure 10(c)) and CPC-FEWS (Figure 10(d)) with the consensus forecast in Figure 4, we can see that the most likely predicted anomaly was the same as observed, broadly indicating the regions of excess rainfall related to Zone II and the regions of below average rainfall along the coast. This is encouraging, as long-range prediction of seasonal average rainfall totals for sub-Saharan Africa remains a major challenge.

In 2012, as there was no strong large-scale SST anomaly pattern driving the WAM, the season was dominated by shorter term phenomena (e.g. the MJO). Whilst a broader understanding of intraseasonal variability (e.g. Janicot *et al.*, 2010) relating to such phenomena has been achieved through the African Monsoon Multidisciplinary Analysis (AMMA) field campaign (2005–2010), predictive skill remains low as the modes are controlled both by internal atmospheric dynamics and land–surface interactions (as is the case with AEWs – see Cornforth *et al.*, 2009). How these sub-seasonal processes are influenced by SST-forcing remains an active topic of research (e.g. Losada *et al.*, 2012) with recent results emphasizing the need to consider the global climate system for successful seasonal forecasts.

Societal consequences and concluding remarks

The active 2012 WAM resulted in above average rainfall throughout the region, with groundwater and rivers (especially Senegal, Niger, and Chad Lake) refilling after the long dry spell. The human cost however, was severe, with many cities and rural communities experiencing flash or riverine floods, particularly in Niger, Chad, Senegal and Nigeria. Amongst all this, we need to repeat that 2012 generated the third biggest food crisis to hit the region in the last seven years. The important question is: what can we do now to help the people living in the Sahel to avoid this recurrent cycle of crises? How can the communities build resilience and bounce back in the face of persistent extreme hydrological events and environmental change?

At the Africa Climate Exchange (AfClix; see Cornforth, 2013), we have been working hard to support and/or open new channels for communication between scientists (physical and social), communities and decision-makers (NGO and government) in the region, to listen and learn about the actual needs people have and their priorities for weather and climate information (Figure 11). We work to explore strategies about how to manage climate risk and what actions are necessary in the face of the sort of extreme

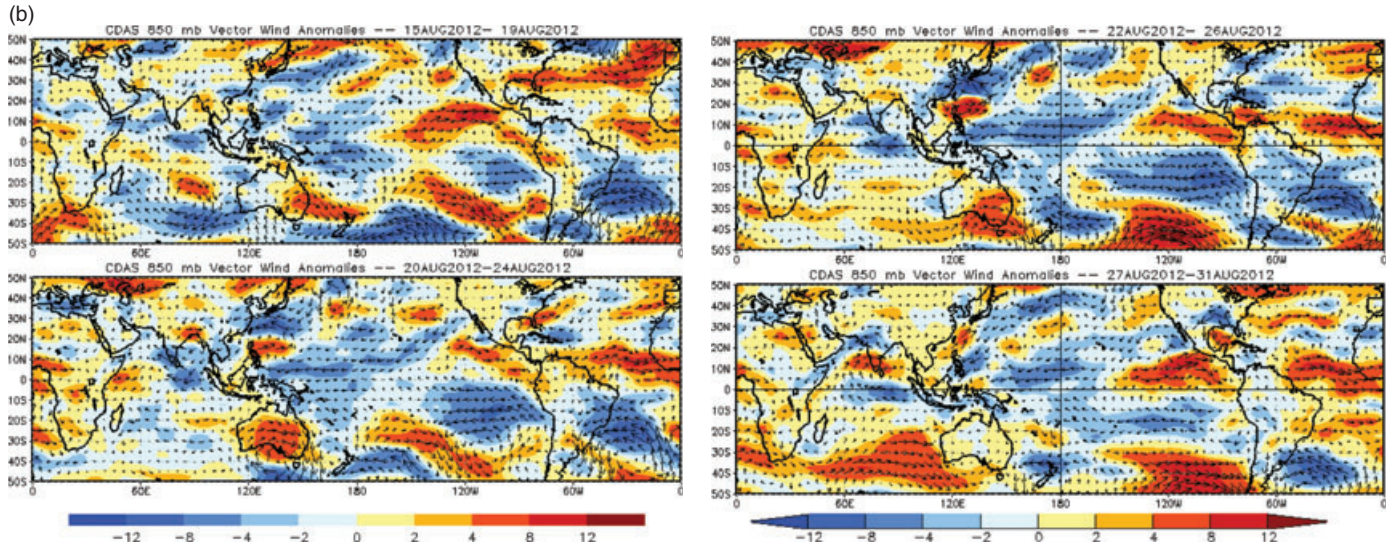
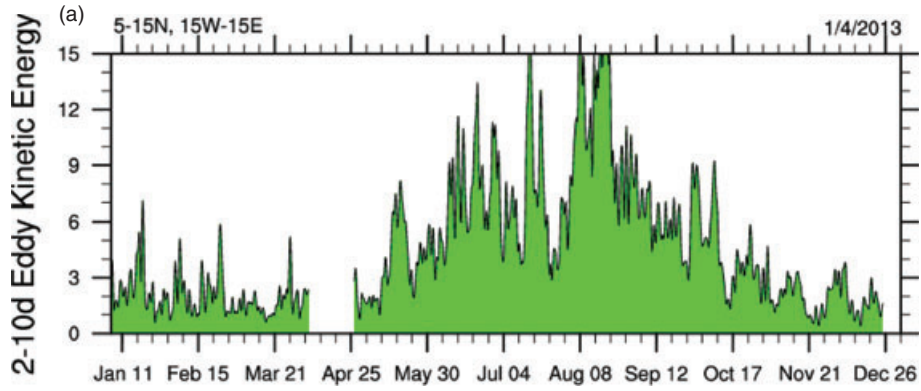


Figure 9. (a) African Easterly Wave 2012 activity represented by the 2–10 day filtered 700mb Eddy Kinetic Energy averaged over 5–15°N, 15°W to 15°E. AEW activity increases in mid-June and August. Source: Michael Ventrice, University at Albany, New York. (b) 850mb westerly wind anomalies: 15–31 August. Strong westerly wind anomalies continue across the tropical Atlantic and into western Africa in association with enhanced MJO activity through August. Note that shading denotes the zonal wind anomaly. Blue shades: Easterly anomalies. Red shades: Westerly anomalies. Source: NOAA.

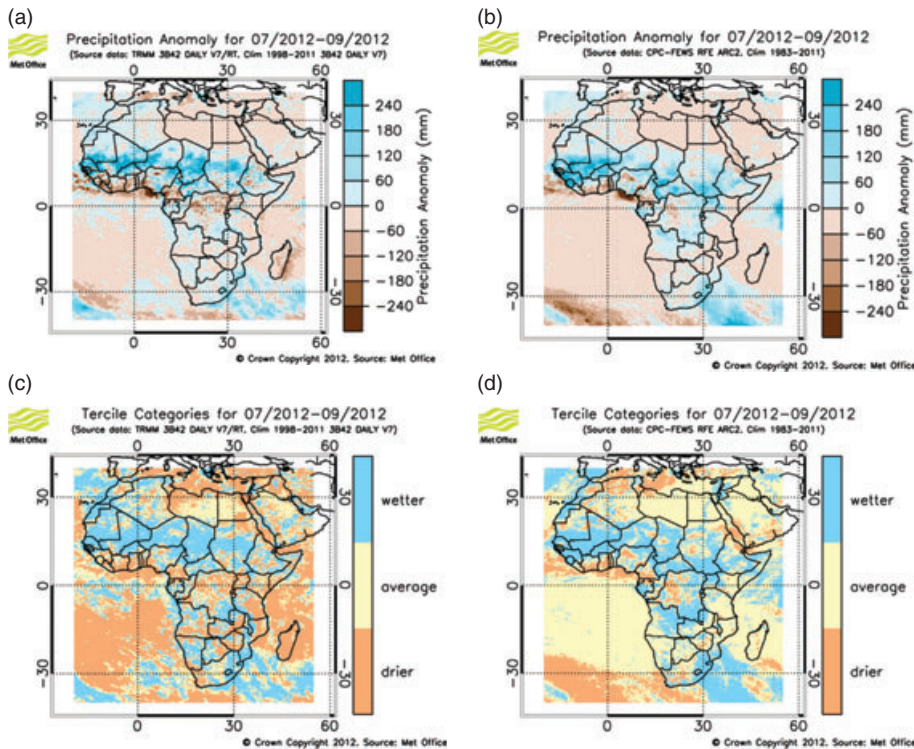


Figure 10. Observed JAS rainfall anomalies from (a) TRMM (relative to 1998–2012); and (b) CPC-FEWS (relative to 1983–2012); (c) Tercile verification plots from TRMM; (d) and CPC-FEWS (c.f. Figure 4). Source: Richard Graham, Met Office.



Figure 11. Communicating climate science – playing the Red Cross ‘Early Warning-Early Action’ Game in Dakar, Senegal, in November 2012 as part of an integrated CDKN-funded HFP-led workshop with the Senegal Met Service (ANACIM), civil society leaders, village chiefs and NGOs, supported by AfClix and other UK-based scientists from the Universities of Liverpool, Oxford, Reading and Sussex and the UK Met Office.

and persistent weather events seen during the 2012 WAM. Combining this conversation with our cutting-edge research offers an effective and practical way forward to help people, and enable capacity on the ground. The application of Rainwatch in Niger and its extension to Sudan and other countries in SSA through AfClix (Boyd *et al.*, 2013; Cornforth, 2013) is tangible evidence of the difference an integrated approach can make in supporting long-term agricultural improvements and helping to address the institutional vulnerabilities in the region. This is the pragmatic way forward to building resilience and reversing the cycle of food shortages and crises in the Sahel.

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