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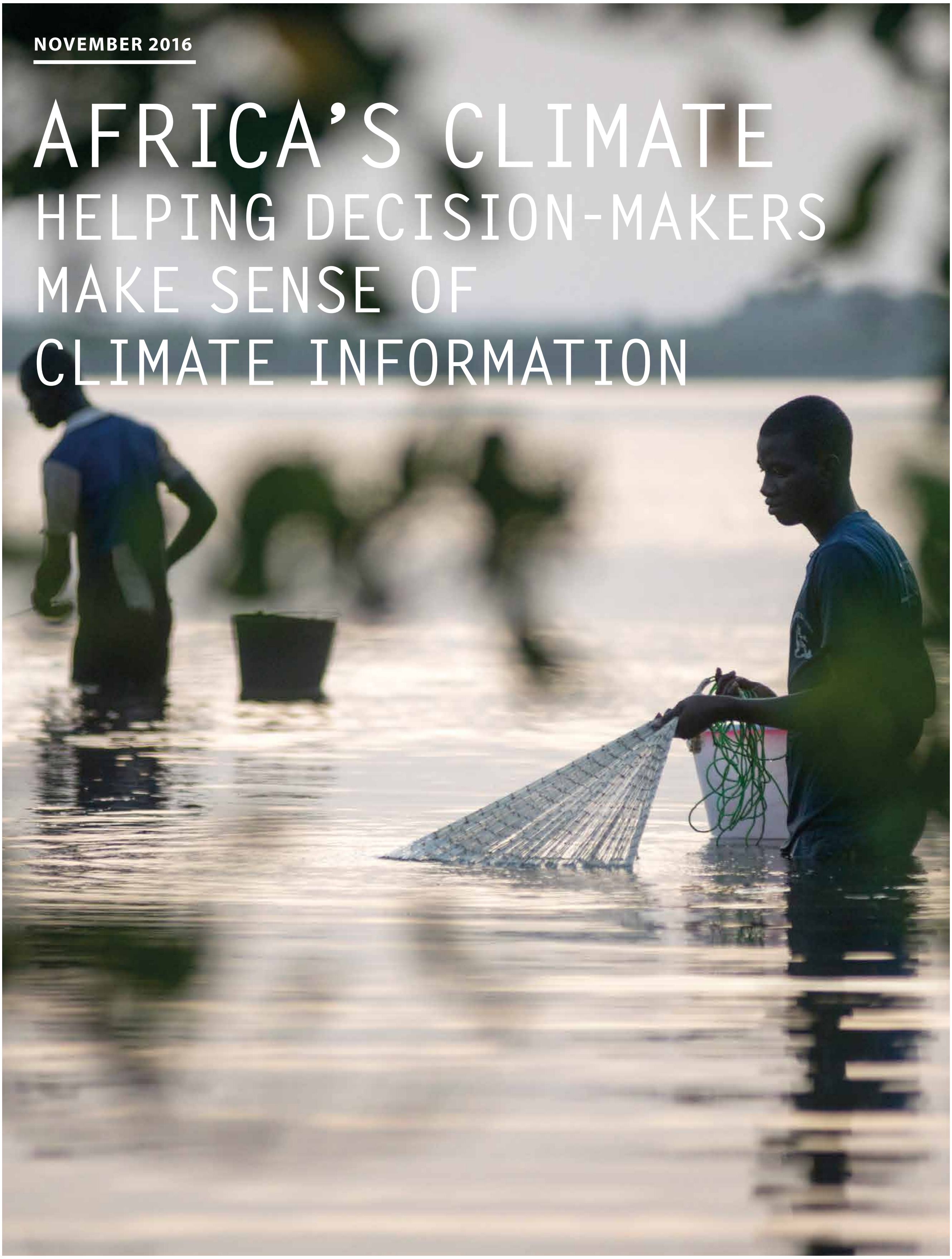
AFRICA'S CLIMATE

HELPING DECISION-MAKERS MAKE SENSE OF CLIMATE INFORMATION



FUTURE
CLIMATE
FOR
AFRICA

GENERAL READERS

WEST AFRICA
REGIONAL
OVERVIEW

A CENTURY OF CLIMATE CHANGE: 1950–2050

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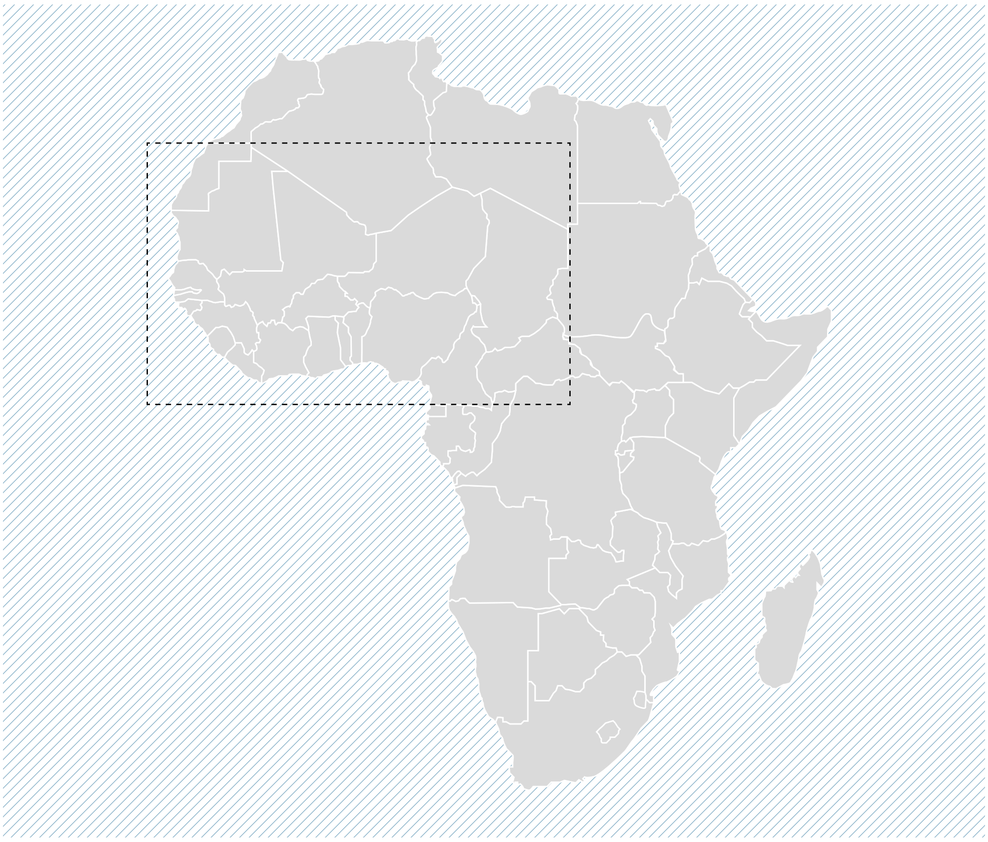

NEED TO KNOW

In west Africa, people's lives and livelihoods are significantly impacted by season to season, and year to year variability in climate. Climate change will worsen these impacts.

- Decision-makers need reliable climate projections in order to plan effectively for warmer temperatures, altered rainfall patterns, and changing frequency of droughts and heatwaves.
- Scientists have greater confidence in projections of future temperature change from existing climate models, than for future rainfall change.
- Scientists are working on both improving understanding of existing models, and on improving the next generation of climate models, to produce more reliable projections.
- Scientists are also working to better understand the role of human-caused greenhouse gas emissions and sea surface temperatures in driving the west African climate, especially rainfall.

SETTING THE SCENE

Some of the world's poorest people live in west Africa. Since the 1950s, this region has experienced extreme variations in climate, relative to anywhere else on Earth. Extremes of drought, flooding and temperature have had severe impacts on populations that are highly exposed to these sorts of hazards. This is, in part, due to a strong dependence on rain-fed agriculture, poor sanitation and limited access to clean water. This is particularly true for the Sahel region.

Historical climate records have documented the severity of the recent drought during the 1970s–1990s, and subsequent recovery in the 2000s. More work, however, needs to be done to understand the natural and human causes that drive these trends.

Average temperatures in west Africa are already rising. Since 1950, weather stations have measured an increase of around 1°C across the region

Another area of research is to understand how the regional climate responds to large-scale changes in climate forcings, such as the temperature of surface water in nearby oceans, and land use change.

The models that simulate west Africa's future climate often disagree with one another, particularly in terms of how rainfall patterns may change. This makes it difficult for regional stakeholders to make effective adaptation plans.

CLIMATE IS ALREADY CHANGING IN WEST AFRICA

Average temperatures in west Africa are already rising. Since 1950, weather stations have measured an increase of around 1°C across the region.[1] However, in the Sahel, the change is

1 Morice, C. P., J. J. Kennedy, N. A. Rayner, and P. D. Jones, 2012: Quantifying uncertainties in global and regional temperature change using an ensemble of observational estimates: The HadCRUT4 data set. J. Geophys. Res., 117, D08101, doi:10.1029/2011JD017187. http://doi.wiley.com/10.1029/2011JD017187 (Accessed September 25, 2015).

higher: 1.5 to 2°C. Monthly temperature records show that the warmest months of the year – April, May, and June – have experienced even greater increases in temperature of up to 3°C,[2] mainly due to warmer night time temperatures.

Rainfall trends across the Sahel from 1950 to 2010 fall into three distinct periods:

- 1950s and 1960s: above average monsoon rains.
- 1970s, 1980s and 1990s: a period of extended drought, where the monthly rainfall was lower than the average, by about 30mm per month.
- 2000s and 2010s: weather records show a recovery in rainfall, albeit with increased variability in year to year rainfall. Looking at the figures taken from rain gauges across the Sahel,[3] it looks as though this 'recovery' is actually accompanied by greater volumes of rain falling during extreme storm events, and by a general decrease in the number of rainy days. The contribution of extreme rainy days to the annual total, during this time, was higher than at any point during the 1950–2010 period.

What is driving these historical changes?

Many studies have linked Sahel rainfall variability to change in sea surface temperatures, increases in atmospheric carbon dioxide, and air pollution in the northern hemisphere

Understanding whether these changes are due to normal decade to decade variability, or whether they are a response to human-induced or natural drivers of global change, can help improve projections of future change. For example, many studies have linked Sahel rainfall variability to change in sea surface temperatures, increases in atmospheric carbon dioxide, and air pollution in the northern hemisphere.

When sea surface temperatures (SSTs) cool in the northern tropical Atlantic, and warm slightly in the South Atlantic, the Sahel tends to become drier.[4, 5, 6] Warmer SSTs in the Indian Ocean also seem to correlate with drought over the Sahel, as well as when there is a large difference in the gradient of surface water temperatures across the eastern Pacific.[7]

Decadal variations in the temperature of surface water in the Mediterranean also influences rainfall trends in the Sahel.[8, 9] However, there is still debate about whether this is due to natural fluctuations, human activity, or a combination of both. There is some evidence

2 Guichard, F., L. Kergoat, F. Hourdin, C. Léauthaud, J. Barbier, E. Mougin and B. Diarra, 2015. Le réchauffement climatique observé depuis 1950 au Sahel. in Les sociétés rurales face aux changements climatiques et environnementaux en Afrique de l'Ouest (Sultan B, Lalou R, Amadou Sanni M, Oumarou A et Soumaré M A eds.), IRD Editions, 23–42.

3 Panthou, G., T. Vischel, and T. Lebel, 2014. Recent trends in the regime of extreme rainfall in the Central Sahel. Int. J. Climatol., n/a–n/a, doi:10.1002/joc.3984. http://doi.wiley.com/10.1002/joc.3984 (Accessed March 26, 2014).

4 Giannini, A., R. Saravanan, and P. Chang, 2003. Oceanic forcing of Sahel rainfall on interannual to interdecadal time scales. *Science*, 302, 1027–1030, doi:10.1126/science.1089357. www.ncbi.nlm.nih.gov/pubmed/14551320 (Accessed July 13, 2016).

5 Biasutti, M., I. M. Held, A. H. Sobel, A. Giannini, 2008. SST Forcings and Sahel Rainfall Variability in Simulations of the Twentieth and Twenty-First Centuries. J. Climate, 21, 3471–3486, doi:10.1175/2007JCLI1896.1. http://journals.ametsoc.org/doi/abs/10.1175/2007JCLI1896.1 (Accessed August 25, 2014).

6 Folland, C. K., T. N. Palmer, and D. E. Parker, 1986. Sahel rainfall and worldwide sea temperatures, 1901–85. Nature, 320, 602–607.

7 Janicot, S., A. Harzallah, B. Fontaine, and V. Moron, 1998. West African Monsoon Dynamics and Eastern Equatorial Atlantic and Pacific SST Anomalies (1970–88). J. Clim., 11, 1874–1882. http://journals.ametsoc.org/doi/full/10.1175/1520-0442-11.8.1874 (Accessed June 3, 2016).

8 D. P. Rowell, C. A. Senior, M. Vellinga, and R. J. Graham, 2016. Can climate projection uncertainty be constrained over Africa using metrics of contemporary performance? Clim. Change, 134, 621–633, doi:10.1007/s10584-015-1554-4. http://link.springer.com/10.1007/s10584-015-1554-4 (Accessed July 21, 2016).

9 Gaetani, M., B. Fontaine, P. Roucou, and M. Baldi, 2010. Influence of the Mediterranean Sea on the West African monsoon: Intraseasonal variability in numerical simulations. J. Geophys. Res., 115, D24115, doi:10.1029/2010JD014436. http://doi.wiley.com/10.1029/2010JD014436 (Accessed July 25, 2016).

to suggest that air pollution related to human activity, especially in the northern hemisphere during the latter part of the 20th century, may also be partially responsible for drought in the Sahel.[10, 11] Interestingly, current levels of carbon dioxide in the atmosphere tend to push up rainfall in west Africa, yet this is countered by present-day sulphur dioxide concentrations related to air pollution, which tend to lead to reduced rainfall across the region.

While sea surface temperatures were undoubtedly the main driver of drought in the Sahel from the 1970s to the 1990s, vegetation cover has also been shown to potentially feed back into rainfall variability in west Africa. The time-lagged response of vegetation on a year to year timescale has for example been shown to have exacerbated the Sahelian drought via reduced evaporation and transpiration. The link between the land surface condition and rainfall is also evident at shorter time scales, where the presence of woodlands in savannah regions, and wet or dry patches of soil in the Sahel, have been shown to enhance localised rainfall, particularly during the monsoon.

FUTURE CLIMATE: WEST AFRICA BY 2050

Temperature increases

Average temperatures over west Africa are projected to increase by between 1.5°C and 4°C by mid-century, relative to 1986–2005

Average temperatures over west Africa are projected to increase by between 1.5°C and 4°C by mid-century, relative to 1986–2005.[12] Larger increases are expected in the Sahel and the Sahara Desert compared to the Guinea coast, especially under a high end climate change scenario. Extremes of temperature are expected to change, with night time (minimum daily) temperatures expected to increase at a faster rate than day time (maximum daily) temperatures. The number of heatwave days each year is also projected to increase significantly by mid-century, especially in the western Sahel.[13] Despite uncertainty on the range of future temperature change, this is still a confident projection due to our understanding of the processes that drive this change.

Rainfall and drought

The projected changes in rainfall trends by the 2050s are less certain than for temperature. For large parts of west Africa, climate models do not agree on whether rainfall will increase or decrease, and in many cases, models show significant trends in both directions.[14] Relative to 1986–2005, the rainfall projections for July to September in the 2050s range between -40% and +20% in the western Sahel, and between -20% and +40% in the central and

10 Ackerley, D., B. B. B. Booth, S. H. E. Knight, E. J. Highwood, D. J. Frame, M. R. Allen, and D. P. Rowell, 2011. Sensitivity of Twentieth-century Sahel Rainfall to Sulfate Aerosol and CO2 Forcing. J. Clim., 24, 4999–5014, doi:10.1175/JCLI-D-11-00019.1. http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-11-00019.1 (Accessed November 27, 2015).

11 Booth, B. B. B., N. J. Dunstone, P. R. Halloran, T. Andrews, and N. Bellouin, 2012. Aerosols implicated as a prime driver of twentieth-century North Atlantic climate variability. Nature, 484, 228–232, doi:10.1038/nature10946. http://dx.doi.org/10.1038/nature10946 (Accessed March 1, 2013).

12 Niang, I., O. C. Ruppel, M. A. Abdrabo, A. Essel, C. Lennard, J. Padgham, and P. Urquhart, 2014. Africa. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1199–1265.

13 Vizy, E. K., and K. H. Cook, 2012. Mid-Twenty-First-century Changes in Extreme Events over Northern and Tropical Africa. J. Clim., 25, 5748–5767, doi:10.1175/JCLI-D-11-00693.1. http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-11-00693.1 (Accessed December 3, 2015).

14 Niang, I. et al, 2014.

eastern Sahel.[15, 16] Additionally, rainfall projections generally show delayed onset of early season rainfall (June and July), particularly in the western Sahel, and an increase in late season rainfall (September and October), particularly in the central and eastern Sahel.

It is important to be clear that while the majority of models project a general drying trend in the west and a wetting trend in the central and eastern Sahel, equally credible models do not project this spatial pattern of change. This therefore brings into question the mechanisms by which models project rainfall changes, and emphasises the importance of understanding these processes in order to improve the reliability of model projections.

Weather impacts on people are most commonly experienced via high impact events, such as very intense rainfall or long dry spells. Under a warming climate, we might expect that the intensity of rainfall events will increase, because a warmer atmosphere can hold more water.[17] Regional climate modelling studies[18, 19] confirm this by projecting trends of more intense, but less frequent, rainfall events in the 21st century. These projections appear to indicate a continuation of the trends found in rain gauge observations since 2000, where high year to year rainfall variability was accompanied by increases in intense rainfall and decreases in the number of wet days.

FUTURE CHALLENGES

Normal variation in the climate – season to season, year to year, and decade to decade – already have a significant impact on people's lives and livelihoods in west Africa. More work still needs to be done to reliably project how climate change will alter these normal variations, particularly for precipitation in the region. It is therefore imperative that climate scientists develop new approaches to understand why projections from climate models differ, and provide expert judgement on which models are the most trustworthy for use by stakeholders.

In order to do this, there are two key challenges facing climate scientists.

First, there is a need to better understand the historical drivers of observed climate trends, such as the links between sea surface temperatures and air pollution, and to use this knowledge to identify models that have performed well for reconstructing the historical climate of the region.

Second, there is also the need to understand the mechanisms of future change in models, and to use this knowledge to identify models that produce a trustworthy projection of future change. With more robust and reliable projections of future change, stakeholders in the region will be able to make more confident adaptation plans that improve the lives and livelihoods of the people of west Africa.

15 Rowell et al, 2016.

16 Niang, I., et al., 2014. 1199–1265.

17 Giorgi, F., E. -S. Im, E. Coppola, N. S. Diffenbaugh, X. J. Gao, L. Mariotti, and Y. Shi, 2011. Higher Hydroclimatic Intensity with Global Warming. J. Clim., 24, 5309–5324, doi:10.1175/2011JCLI3979.1.

18 Sylla, M. B., F. Giorgi, J. S. Pal, P. Gibba, I. Kebe, and M. Nikiema, 2015. Projected Changes in the Annual Cycle of High Intensity Precipitation Events over West Africa for the Late 21st century. J. Clim., 28, 6475–6488, doi:10.1175/JCLI-D-14-00854.1. http://journals.ametsoc.org/doi/abs/10.1175/JCLI-D-14-00854.1 (Accessed June 13, 2015).

19 Vizy and Cook, 2012.

FCFA'S AMMA-2050 PROJECT

Project objectives

AMMA-2050 will improve understanding of how the west African monsoon will be affected by climate change in the coming decades – and help west African societies prepare and adapt. The AMMA-2050 team will investigate how physical processes interact to cause 'high impact weather events' such as storms and heawaves that affect lives and livelihoods. Not only will they look at how the total amount of rainfall is likely to change – but also at how rainfall is likely to be distributed throughout the wet season. For example, heavy rainfall concentrated in just a few hours places great stress on human settlements, infrastructure and agriculture. By applying expert judgement, they will identify adaptation options in water resources and agriculture. See www.futureclimateafrica.org/project/amma-2050/

The organisations involved in AMMA-2050 are:

- Centre for Ecology and Hydrology (UK)
- National Agency for Civil Aviation and Meteorology (Senegal)
- Félix Houphouët – Boigny University
- University of Cape Coast
- Senegalese Institute for Agricultural Research
- VNG Consulting Limited
- University of Leeds
- Met Office (UK)
- University of Sussex
- Institute for Development Research – Hydrology and Environment (France);
- Pierre Simon Laplace Institute – Oceanic and Climate Laboratory
- French Agricultural Research Centre for International Development
- National Centre for Meteorological Research – the Meteorological Atmosphere Study Group (France)

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