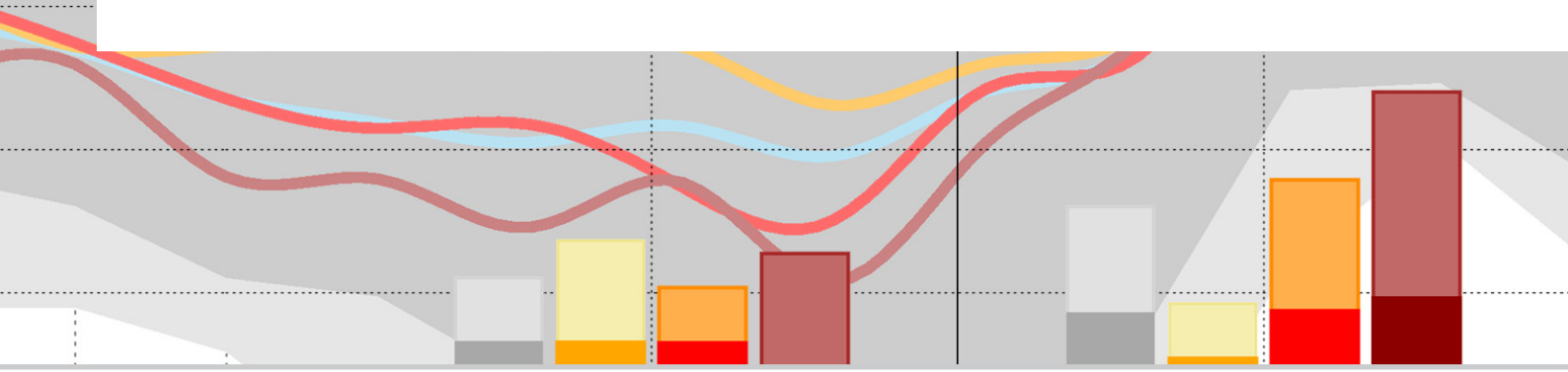
Climate-Fact-Sheet

Burundi - Malawi - Rwanda - Tanzania



Abstract

The eastern African region encompassing Burundi, Malawi, Rwanda and Tanzania is characterized by tropical (Aw) to subtropical climates (Cwa). With the exception of a narrow coastal strip in Tanzania, most of the region can be classified as highland above about 900 m a.s.l. (including the Kilimanjaro, which stretches to 5895 m a.s.l.). Temperature distribution is rather uniform throughout year and ranges between 20 to 25 °C. Rainfall is strongly seasonal. Over the northern parts of the region (located just south of the equator) the Inter-Tropical Convergence Zone (ITCZ) crosses twice a year leading to two distinct wet periods - the “short rains” in the October to December period and the “long rains“ from March to May. The southern parts of the region experience only one rainy season extending from September/October to April/May. Annual rainfall amounts vary from about 600 mm in some central parts of Tanzania to about 2000 mm at the border between Malawi and Tanzania.

Mean annual temperature in the region has slightly increased since the beginning of the 20th century. For the future, temperature projections from global climate models suggest a moderate increase in temperature. For the end of the century a warming in the range of 2.1 to 3.6 °C (compared to the reference period from 1961 to 1990) is likely. Furthermore, a strong increase in the duration of heat waves as well as a strong reduction in cold spell length are projected.

A tendency for a slight increase in annual total precipitation has been observed in the past. For the future, climate models project a continuation of the positive trend in precipitation amounts. For the end of the century an increase in annual total precipitation in the range of 2 to 14 percent (compared to the reference period from 1961 to 1990) is likely. The largest increase is projected to occur during the rainy season (up to 17 percent). Furthermore, projections suggest a slight increase in the duration of dry spells as well as a tendency towards more intense and more frequent rainfall events. The climatic water balance is projected to increase in the future. However, the projection of change in the water balance is affected by a large spread and therefore deemed to be not very robust. The same holds true for the robustness of projected changes in solar irradiance and mean wind speed, with the median projections suggesting little change over the 21st century.

Coastal areas of Tanzania have experienced changes in mean sea level, over the past 30 years, with observations indicating a decrease in mean sea level of about 3.6 mm/yr on average for coastal stations at Zanzibar. Projections of changes in future sea level however are rather uncertain at the moment due to uncertainty about the rate at which ice is lost from land (glaciers and ice sheets), as well as possible changes in ocean circulation.

Zusammenfassung

Das Klima der Region, welche die Länder Burundi, Malawi, Ruanda und Tansania umschließt, kann als vorwiegend tropisch (Aw) bis subtropisch (Cwa) klassifiziert werden. Abgesehen von einem schmalen Küstenstreifen ist die Region sehr hoch gelegen (überwiegend über 900 m ü. NN bis hin zum Kilimandscharo-Massiv auf 5895 m ü. NN). Die Jahresmitteltemperatur in der Region schwankt zwischen ca. 20 °C in den Plateau-Regionen bis ca. 25 °C an der Küste, mit geringen Schwankungen im Jahresgang. Der Niederschlag in der Region ist stark saisonal. Im nördlichen (äquatornahen) Teil treten zwei Regenzeiten auf, die “short rains” im Zeitraum Oktober bis Dezember und die “long rains“ von März bis Mai. In den südlichen Regionen gibt es dagegen nur eine ausgeprägte Regenzeit, die sich von September/Oktober bis April/Mai erstreckt. Der mittlere Jahresniederschlag in der Region schwankt zwischen ca. 600 mm in zentralen Regionen von Tansania bis zu mehr als 2000 mm im Grenzgebiet von Malawi und Tansania.

Beobachtete Jahresmitteltemperaturen zeigten in der Vergangenheit einen leicht zunehmenden Trend. Für die Zukunft projizieren Klimamodelle für die Region einen moderaten Temperaturanstieg. Zum Ende des Jahrhunderts kann eine Temperaturzunahme zwischen 2.1 und 3.6°C im Vergleich zum Basiszeitraum von 1961 bis 1990 als wahrscheinlich betrachtet werden. Einhergehend mit dem Temperaturanstieg sind eine starke Ausdehnung von Hitzeperioden sowie eine deutliche Verkürzung von Kälteperioden.

Für den Jahresniederschlag konnte in der Vergangenheit eine leichte Tendenz zur Zunahme beobachtet werden. Für die Zukunft projizieren Klimamodelle tendenziell eine Fortführung des positiven Niederschlagstrends. Zum Ende des 21. Jahrhunderts kann eine Niederschlagszunahme zwischen 2 und 14% im Vergleich zum Basiszeitraum von 1961 bis 1990 als wahrscheinlich betrachtet werden. Weiterhin wird eine Tendenz zur Zunahme von Starkregenereignissen und eine generelle Ausdehnung von Trockenperioden projiziert. Auch für die klimatologische Wasserbilanz in der Region projizieren Klimamodelle generell eine Zunahme, jedoch ist diese Größe mit großen Unsicherheiten behaftet. Für die solare Einstrahlung und die mittlere Windgeschwindigkeit werden nur geringe Änderungen projiziert, aber auch diese Größen können nur bedingt verlässlich von Klimamodellen wiedergegeben werden.

Der Meeresspiegel an der Küste von Tansania ist in den letzten 30 Jahren leicht gefallen (~ -3.6 mm/Jahr). Für die Zukunft wird allerdings ein genereller Anstieg erwartet, allerdings kann derzeit keine belastbare Aussage über die zukünftige Anstiegsrate getroffen werden.

On behalf of KFW

BMZ Federal Ministry for Economic Cooperation and Development

CSC Climate Service Center Germany

An institution of Helmholtz-Zentrum Geesthacht

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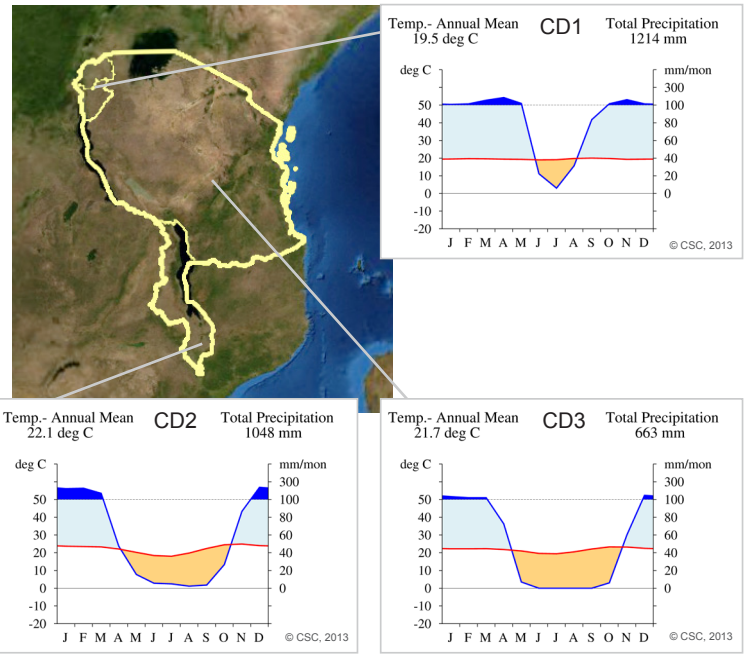
Current climate

Observed mean values are taken from literature and available global data sets (averaged over the whole region):

- Major climate zones (see also climate diagrams - CD1-3): Mainly tropical climate with dry winters (Aw - see CD1 & CD2). Some central parts of Tanzania and parts of Malawi have temperate climate with hot summers and dry winters (Cwa - see CD3).
- Annual mean temperature: 22.1 °C
- Annual total precipitation: 1070 mm/yr
- Annual mean actual evaporation: 830 mm/yr
- Annual mean climatic water balance: ~ 240 mm/yr
- Intensity of heavy rain events*: 25.7 mm/day
- Mean duration of dry spells*: 21 days
- Mean duration of heatwaves*: 7 days
- Mean duration of cold spells*: 7 days
- Annual mean solar irradiance (surface): 1550 kWh/(m² and yr)
- Annual mean wind speed (10 m above surface): 2.4 m/s

Reported recent extreme events:

- Several intensive droughts occurred over the last years e.g. in 2005 in Burundi and Malawi (5.4 Mio. people affected).
- Also several flood-events occurred in the recent past (e.g. 2001 in Malawi) and affected the lives of many people.



The climate parameters marked with * are defined in the manual „How to read a Climate-Fact-Sheet". Whenever mentioned in the fact-sheet, statistical significance is indicated at the 95 percent confidence level. The description of the climate zones is based on the Köppen-Geiger climate classification.

Historical climate trends (based on the global CRU data set and literature sources)

- Mean annual temperature has slightly increased by approximately 0.5 °C over the major parts of the region since the beginning of the 20th century. This increase is statistically significant over Burundi, Rwanda and the north-eastern parts of Tanzania. For the coastal parts of the region, no trend in annual mean temperature was observed.
- For annual total precipitation a tendency for a slight increase (less than 5 percent) was observed during the last century.
- No clear trend was observed in the cases of minimum and maximum temperature in the region.
- Glaciers at the Kilimanjaro are shrinking, most probably related to a drastic drop in atmospheric moisture at the end of the 19th century and the ensuing drier climatic conditions.

Summary of projected future climate (for the end of the century and combined for all scenarios)

Temperature The median projection of change in annual mean temperature is for an increase of 2.9 °C by 2100, with projected change very likely to fall in the range from 1.7 to 4.1 °C. Confidence in these figures is medium. The change in temperature can be considered to be moderate. The median projection of change in maximum temperature is for an increase of 2.5 °C by 2100 and in the minimum temperature for an increase of 3.0 °C.

Heatwaves The median projection of change in the duration of long-lasting heatwaves is for an increase of 27 days by 2100, with projected change very likely to fall in the range from 9 to 104 days. Confidence in these figures is medium. The change in the duration of long-lasting heatwaves can be considered to be strong.

Cold spells The median projection of change in the duration of long-lasting cold spells is for a decrease of 6 days by 2100, with projected change very likely to fall in the range from -9 to -3 days. Confidence in these figures is high. The change in the duration of long-lasting cold spells can be considered to be strong.

Solar irradiance The median projection of change in annual mean solar irradiance is for no substantial change until 2100, with some projections showing an increase and some a decrease. Projected change is very likely to fall in the range from -4 to +2 percent. Confidence in these figures is low. The change in annual mean solar irradiance can be considered to be weak.

Precipitation The median projection of change in annual total precipitation is for an increase of 8 percent by 2100, but some projections show a slight decrease. Projected change is very likely to fall in the range from -1 to +22 percent. The projected increase in precipitation is strongest in the rainy season from September to May (+5 to +17 percent), a slight decrease is projected for the dry season (up to -10 percent). Confidence in these figures is medium. The change in annual total precipitation can be considered to be moderate.

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Evaporation The median projection for annual mean actual evaporation is for a slight increase of 4 percent by 2100, but some projections show a slight decrease. Projected change is very likely to fall in the range from -5 to +10 percent. Confidence in these figures is medium. The change in annual mean actual evaporation can be considered to be weak.

Water balance The median projection of change in the annual mean climatic water balance is for an increase of 18 percent by 2100, but some projections show a decrease. Projected change is very likely to fall in the range from -7 to +106 percent. Confidence in these figures is medium. The change in the annual mean climatic water balance can be considered to be moderate.

Dry spells The median projection of change in the duration of long-lasting dry spells is for a slight increase of 2 days by 2100, but some projections show a decrease. Projected change is very likely to fall in the range from -1 to +12 days. Confidence in these figures is medium. The change in the duration of long-lasting dry spells can be considered to be weak.

Heavy rains The median projection of change in the intensity of heavy rain events is for an increase of 12 percent by 2100, with projected change very likely to fall in the range from +5 to +29 percent. The median projection for the frequency of heavy rain events is for an increase of 32 percent by 2100. Confidence in these figures is medium. The change in the intensity and frequency of heavy rain events can be considered to be moderate.

Wind speed The median projection of change in annual mean wind speed is for no substantial change until 2100, with some projections showing a decrease and some projections a slight increase. Projected change is very likely to fall in the range from -10 to +4 percent. Confidence in these figures is low. The change in the annual mean wind speed can be considered to be weak.

Sea Level Global mean sea level is projected to increase by 18 to 59 cm by the end of the 21st century. Confidence in these projections is low. Local sea level change can be substantially different from global mean sea level projections.

Note: The Climate-Fact-Sheets provide an overview of projected possible changes for selected climate parameters at the national or regional level. The Climate-Fact-Sheets are generated on the basis of the best currently available multi-model ensembles of regional and/or global climate models. Accordingly, the Climate-Fact-Sheets provide a first impression of the magnitude of potential future climate change averaged over a given country/region. As such, the information presented in the Climate-Fact-Sheets does not contain information on the finer local scale changes that may occur, and which may be of more interest, in for example, impact or adaptation studies. The Climate-Fact-Sheets are not intended, nor were they designed, to provide this kind of information. If more local scale information is the nature of your interest, or requirement, then alternative methods or tools should be used. Finally, the description of the current climate of the country as well as the observed historical trends is kept to a minimum, as the focus of the Climate-Fact-Sheets is on projected future changes.

Data sources and references

Data sources:
All projections (except information on the sea level) are based on the results of the global climate model projections, which are the base of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4 - www.ipcc.ch).
Information on current climate and historical trends, as well as the climate diagrams, are based on the available global data set compiled by the Climatic Research Unit from the University of East Anglia. Also data from the so called WATCH forcing data (compiled within the EU-project WATCH - Water and Global Change) has been used. Data on evaporation, wind speed and solar irradiance has been taken from reanalyses data (ERA-interim) compiled by the European Centre for Medium-Range Weather Forecasts (ECMWF).

References:
Information on recent extreme events and their impacts has been taken from: http://www.preventionweb.net

Information on the classification of climate zones and of the current climate has been taken from the following literature:
Kottek, M., Grieser J., Beck C., Rudolf B. and Rubel F. (2006): World Map of the Köppen-Geiger climate classification updated. In: Meteorologische Zeitung, 15, 259-263.
Oki T. and S. Kanae (2006): Global Hydrological Cycles and World Water Resources. Science 313, 1068.

Information on historic trends and for projected future changes (mainly for cross-checking) has been taken from the following literature (in alphabetical order):
Christensen, J.H. et al. (2007): Regional Climate Projections. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Climate Change (2007): Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry et al. Eds.,Cambridge University Press, Cambridge, UK, 469-506.
Kaser G. et al. (2004): Modern glacier retreat on Kilimanjaro as evidence of climate change: observations and facts. International Journal of Climatology Volume 24, Issue 3, pages 329–339.
Lyimo, T. J. (2011): Distribution and abundance of the cyanobacterium Richelia intracellularis in the coastal waters of Tanzania. J Ecol Nat Environ, 3, 85-94.
Malawi Meteorological Service (2006): The climate of Malawi. Available via: http://www.metmalawi.com/climate/climate.php

Information on historic and projected changes in mean sea level has been taken from the following literature (in alphabetical order):
Bindoff, N.L. et al. (2007): Observations: Tropical Climate Change and Sea Level. In: Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Dasgupta, S et al. (2009): Sea-Level Rise and Storm Surges. A Comparative Analysis of Impacts in Developing Countries. The World Bank Development Research Group Environment and Energy Team, Policy Research Working Paper 4901.
Dasgupta, S et al. (2011): Exposure of developing countries to sea-level rise and storm surges. Climatic Change 106:567–579, DOI 10.1007/s10584-010-9959-6.
Dasgupta, S et al. (2009): The impact of sea level rise on developing countries: a comparative analysis Exposure of developing countries to sea-level rise and storm surges. Climatic Change,93:379–388.
Mahongo S.B. (2009): The Changing Global Climate and its Implication on Sea Level Trends in Tanzania and the Western Indian Ocean Region. Western Indian Ocean J. Mar. Sci. Vol. 8, No. 2, pp. 147 - 159.
Nicholls R.J. and Cazenave A. (2010): Sea-level rise and its impact on coastal zones. Science 328,1517.
Rahmstorf, S (2010): A new view on sea level rise. Nature Reports Climate Change, 4.

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Legend

Statistical information:

very likely: light-coloured
(90 % of model simulations)

likely: dark-coloured
(66 % of model simulations)

Median
(50 percent-value of model simulations)

Emission scenarios:

- all scenarios combined
- low scenario (B1)
- medium scenario (A1B)
- high scenario (A2)

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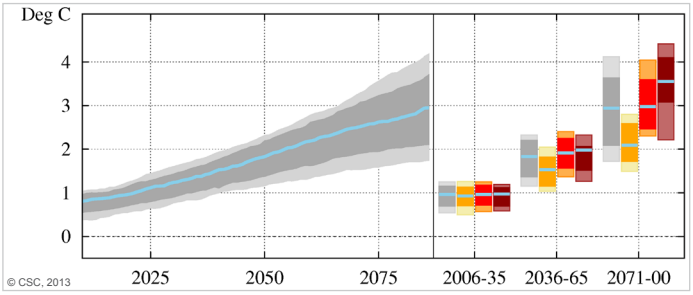
Projections of possible development of temperature, heatwaves and cold spells

Annual mean temperature

- Median projection of change in annual mean temperature is for an increase of 2.9 °C by 2100.
- Likely range: 2.1 to 3.6 °C; very likely range: 1.7 to 4.1°C

Separate scenario examination (by 2100):

- **Low-Scenario B1:** Median +2.1 °C
- **High-Scenario A2:** Median +3.6 °C



Maximum and minimum temperature

The trends of maximum and minimum temperature are consistent with the trend of annual mean temperature depicted above.

- Median projection of change in maximum temperature is for an increase of 2.5 °C by 2100.
- Median projection of change in minimum temperature is for an increase of 3.0 °C by 2100.

in °C	Scenario	Measure	Max-Temperature	Min-Temperature
2071-2100	ALL	Median **likely** very likely	2.5 **1.8 to 3.0** 1.4 to 4.6	3.0 **2.3 to 3.8** 1.6 to 4.4
	B1	Median **likely** very likely	1.8 **1.6 to 2.6** 1.4 to 3.0	2.3 **1.6 to 2.8** 1.6 to 3.1
	A1B	Median **likely** very likely	2.4 **2.3 to 3.3** 2.2 to 4.6	3.2 **2.4 to 3.7** 2.3 to 4.4
	A2	Median **likely** very likely	2.8 **2.6 to 3.8** *	3.8 **3.0 to 4.2** *

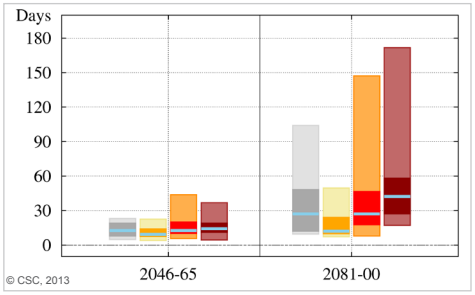
* The amount of available data is not sufficient to project the range for „very likely“ for A2

Heatwaves

- **Median projection of change in the duration of long-lasting heat-waves is for an increase of 27 days by 2100.**
- Likely range: 12 to 48 days; very likely range: 9 to 104 days

Separate scenario examination (by 2100):

- **Low-Scenario B1:** Median +12 days
- **High-Scenario A2:** Median +42 days



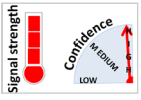
Cold spells*

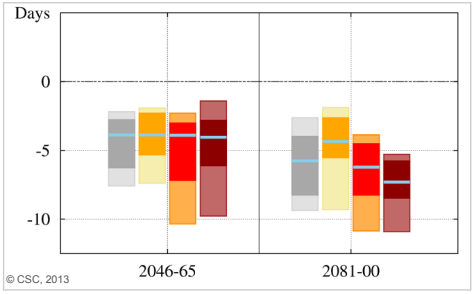
- Median projection of change in the duration of long-lasting cold spells is for a decrease of 6 days by 2100.
- Likely range: -8 to -4 days; very likely range:-9 to -3 days

Separate scenario examination (by 2100):

- **Low-Scenario B1:** Median -4 days
- **High-Scenario A2:** Median -7 days

* Note that it is possible that the absolute decrease in the duration of cold spells might be larger than the actual cold spell length (as given in the current climate section) due to a slight mismatch between models and observations.



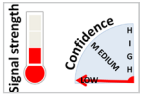


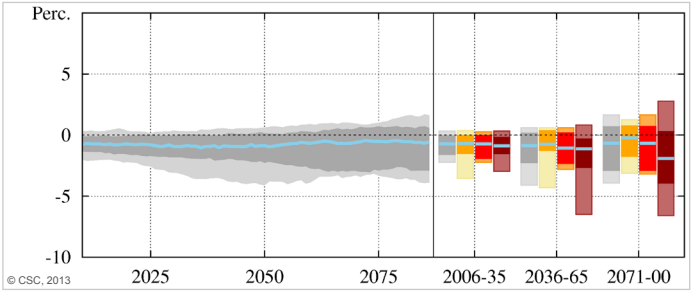
Projections of possible development of solar irradiance

- Median projection of change in solar irradiance is for no substantial change until 2100, with some projections showing an increase and some a decrease.
- Likely range: -3 to +1 percent; very likely range: -4 to +2 percent

Separate scenario examination (by 2100):

- **Low-Scenario B1:** Median ±0 percent
- **High-Scenario A2:** Median -2 percent





All projected changes presented in the Climate-Fact-Sheet are with respect to the reference period from 1961 to 1990.
The evaluation of the signal strength includes not only the actual climate change signal but also the statistical significance of the projected change.
The assessment of the confidence in the climate model projections is based on the models‘ performance in simulating today’s climate as well as on the bandwidth of projected climate change. This bandwidth results from the fact that every climate model projects a slightly different climate change signal.

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Legend

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Median
(50 percent-value of model simulations)

Emission scenarios:

- all scenarios combined
- low scenario (B1)
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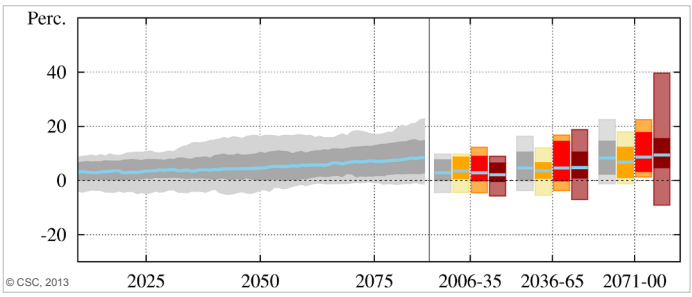
Projections of possible development of precipitation and water availability

Annual total precipitation

- Median projection of change in annual total precipitation is for an increase of 8 percent by 2100, but some projections show a slight decrease.
- Likely range: +2 to +14 percent; very likely range: -1 to +22 percent

Separate scenario examination (by 2100):

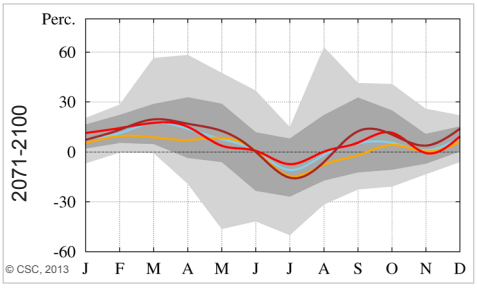
- **Low-Scenario B1:** Median +7 percent
- **High-Scenario A2:** Median +9 percent



Precipitation seasonality

- Median projection of change in total precipitation is for an increase in the rainy season from September to May (+5 to +17 percent) and for a slight decrease during the dry season (up to -10 percent).
- Likely range: -10 to +32 percent (rainy season) and -26 to +22 percent (dry season).

The **A2-Scenario** shows a more pronounced precipitation increase during the rain season than the **B1-Scenario**.

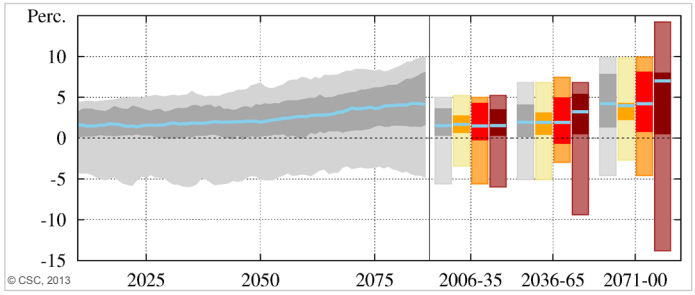


Evaporation

- Median projection for actual evaporation is for a slight increase of 4 percent by 2100, but some projections show a slight decrease.
- Likely range: +1 to +8 percent; very likely range: -5 to +10 percent

Separate scenario examination (by 2100):

- **Low-Scenario B1:** Median +4 percent
- **High-Scenario A2:** Median +7 percent



Climatic water balance (difference between annual mean precipitation and annual mean actual evaporation)

- Median projection of change in the climatic water balance is for an increase of 18 percent by 2100, but some projections show a decrease.
- Likely range: +3 to +40 percent; very likely range: -7 to +106 percent

Separate scenario examination (by 2100):

- **Low-Scenario B1:** Median +16 percent
- **High-Scenario A2:** Median +22 percent

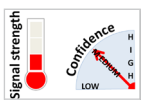
The climatic water balance is derived from projected precipitation and projected actual evaporation amounts. Therefore the bandwidth of both parameters is accumulated in this parameter. Due to this, the climatic water balance shows a rather high bandwidth.

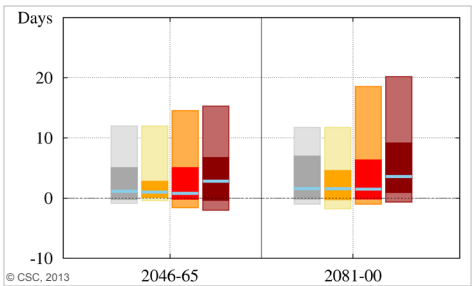
Dry spells

- Median projection of change in the duration of long-lasting dry spells is for a slight increase of 2 days by 2100, but some projections show a decrease.
- Likely range: 0 to +7 days; very likely range: -1 to +12 days

Separate scenario examination (by 2100):

- **Low-Scenario B1:** Median +2 days
- **High-Scenario A2:** Median +4 days





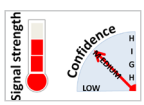
Heavy rains*

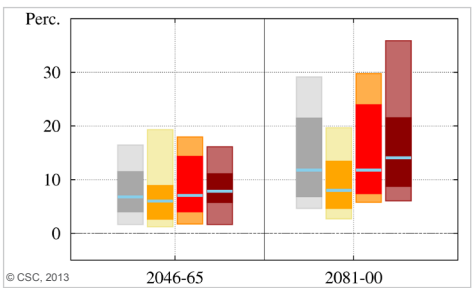
- Median projection of change in the intensity of heavy rainfall events is for an increase of 12 percent by 2100.
- Likely range: +7 to +21 percent; very likely range:+5 to +29 percent

Separate scenario examination (by 2100):

- **Low-Scenario B1:** Median +8 percent
- **High-Scenario A2:** Median +14 percent

A heavy rain event of today's intensity is projected to occur 32 percent more frequently in the future.





* Note that for the intensity of heavy rainfall events only wet days (days with rainfall of more than 1 mm/day) have been considered for the analysis. For the frequency of heavy rainfall events, however, all days (including days without rainfall) have been counted.

This Climate-Fact-Sheet was provided by the Climate Service Center to GIZ-Nele Buenner on the 12.07.2013

Legend

Statistical information:

very likely: light-coloured
(90 % of model simulations)

likely: dark-coloured
(66 % of model simulations)

Median
(50 percent-value of model simulations)

Emission scenarios:

- all scenarios combined
- low scenario (B1)
- medium scenario (A1B)
- high scenario (A2)

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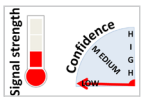
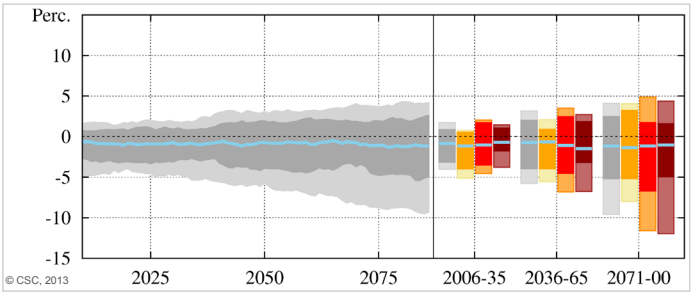
Projections of possible development of wind speed

- Median projection of change in annual mean wind speed is for no substantial change until 2100, with some projections showing a decrease and some projections a slight increase.
- Likely range: -5 to +2 percent; very likely range: -10 to +4 percent

Separate scenario examination (by 2100):

- **Low (B1) and High (A2) Scenario:** Median -1 percent





Projections of possible development of sea level

- Observed global mean sea level rise based on satellite data since 1993 is in the order of 3.0 mm/yr.
- Local sea level however can substantially differ from the global mean sea level.
- At the coastal stations of Zanzibar (Tanzania) a decrease in the mean sea level of about 3.6 mm/yr on average has been observed over the past 30 years.
- According to IPCC AR4 projected global mean sea level rise is in the range of 18 to 59 cm by the end of the 21st century.
- Recent model studies project a stronger increase in global mean sea level with an increase of up to 1 m towards the end of the 21st century.
- Coastal areas of Tanzania are very vulnerable to future changes in sea level. First estimates indicate that about 30% of the coastal population of the region could be affected by a potential sea-level rise of 1m and an increase in storm surges.

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