CHAPTER 4

Future climate change over Southern Africa

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Introduction

There is strong scientific evidence that recent changes in climate are likely attributable to human activities and have resulted in increased annual global temperatures, as well as associated increases in temperature extremes (New et al. 2006; IPCC 2012; Stocker et al. 2013). Global mean annual temperatures have increased by 0.85 °C since 1880 (Stocker et al. 2013), and extreme rainfall events have increased in frequency (Mason et al. 1999; Department of Environmental Affairs 2013). The rate of warming has also increased during the latter half of the 20th century (Qin et al. 2007), while over Africa temperatures are expected to rise at a faster rate than the global mean increase (Stocker et al. 2013). It is clear that Southern Africa is highly vulnerable to climate

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variability, and the region is predicted to be significantly affected by climate change as it poses a critical threat to the water resources, agriculture, health, infrastructure, ecosystem services, and biodiversity, amongst other sectors.

Since the first edition of the South African Risk and Vulnerability Atlas (SARVA), increased public attention has been directed toward climate change (in South Africa and the sub-region), partly due to the COP17 held in Durban in December 2011. Significant progress has been made in projecting and understanding climate change for the southern African region, providing an increasingly robust basis for strategy and policy in various countries as well as the sub-region. For example, in South Africa, the National Climate Change Response White Paper (NCCRP) (Republic of South Africa 2011) was launched in 2011, which supplies the country with a clear roadmap on how the impacts of climate change should be managed through interventions in social, economic and environmental sectors. In response to the NCCRP, the Department of Environmental Affairs (DEA) and the South African National Biodiversity Institute (SANBI) have developed the Long-Term Adaptation Scenarios (LTAS) for South Africa (Department of Environmental Affairs 2013). Globally, in 2014, the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (hereafter referred to as AR5) was released, which provides up to date information on the current state of knowledge relevant to climate change (Stocker et al. 2013).

This chapter presents key messages drawn from recent subsets of future climate projections[1] for the southern African region. Material in this chapter is drawn from Chapter 3 of the Climate Risk and Vulnerability Handbook for Southern Africa (Davis 2011), entitled 'Regional scenarios of future climate change over Southern Africa' (Tadross et al. 2011), as well as recently released studies comparing multiple global circulation models (GCMs), dynamical and statistically downscaled models (Hewitson et al., 2014). Key messages from the latest IPCC report on climate change as well as those from LTAS are also discussed. The latest dynamically downscaled temperature and rainfall projections from the CSIR (NRE) are described for Southern Africa for the short term (2015-2035) and long term (2040-2060 and 2080-2100). Some of the changes are based on the emission scenarios from the IPCC Special Report on Emissions Scenarios (SRES) (Nakicenovic et al. 2000), representing an unmitigated and unconstrained world, whereas others are based on the latest set of Representative Concentration Pathways (RCPs) from IPCC AR5. A multi-model ensemble approach[2] is taken in this chapter in order to describe the range of uncertainty associated with climate change projections.

Determining future climate

Global climate models, or global circulation models (GCMs), comprise the fundamental tools used for assessing the causes of past change and to project long-term future change (2030-2060). These complex computer models represent interactions between the different components of the climate system, such as the land surface, the atmosphere and the oceans. Projections of future climate change by GCMs may provide insight into potential broad-scale changes in the atmosphere and ocean, such as shifts in the major circulation zones and the magnitude of sea level rise. The term 'projection' refers to estimates of future climate possibilities decades into the future.

Since future levels of greenhouse gas emissions in the atmosphere are crucially dependent on our behaviour and policy choices – whether or not we continue to depend on fossil fuels or switch to renewable energy sources, for example – the models are created to simulate climate under a range of emission scenarios. Each scenario represents a plausible future. The IPCC Special Report on Emissions Scenarios (SRES) describes four possible 'story lines' (A1, B1, A2 and B2), each assuming different paths of development for the world. Each scenario has an associated future emissions pathway which describes the amount of greenhouse gases emitted through human activity (Nakicenovic et al. 2000). This is largely why the IPCC reports project future global average temperature change to be within a certain range. The lower estimate is based on an emissions scenario where behaviour and policy translate into lower emissions of greenhouse gases. The higher estimate comprises a 'worst case' scenario, where emissions continue to increase at a rapid rate. It is very important to clearly understand that there are a range of future possibilities, as it follows that we can only suggest futures that may be more likely than others (Tadross et al. 2011:28).

In the AR5 (Stocker et al. 2013), Representative Concentration Pathways (RCPs) replaced the SRES emission scenarios and were used as the basis of the climate projections presented in AR5. The RCPs are named according to their 2100 radiative

1 Projection is a statement of a possible (hopefully likely) future state of the climate system dependent on the evolution of a set of key factors over time (e.g. carbon dioxide emissions).

2 An ensemble of models is used to project different (but equally plausible) climate futures.

forcing level[3]. There are four pathways: RCP2.6, RCP4.5, RCP6.0 and RCP8.5. Whilst RCPs have replaced the SRES emission scenarios in current assessments, the outputs of older SRES GCM simulations and associated downscaled models remain valid, even if they describe a different subset of possible future climates. Therefore, in this chapter we present the outputs resulting from both SRES and RCP simulations.

Determining regional climate change

Global climate models (GCMs) can reliably project changes in temperature, since the warming response is widespread and the physical processes responsible for warming are well-captured by these models. These models are, however, often less-skilled in translating the gathered information into changes in rainfall and other parameters at the local scale. This is due to the fact that GCMs are applied at spatial scales of 200-300 km, and they often cannot capture the physical processes and features of the landscape which are important determinants of local and regional climates. For example, thunderstorms occur on spatial scales which are too small or localised for GCMs to resolve. It thus follows that GCMs tend to be unreliable estimators of rainfall in regions where convection[4] is important. This limits the application of GCM projections for assessments of change at the local scale. For this reason, 'downscaling' techniques, which translate changes in the large-scale atmospheric circulation (which GCMs generally reproduce well) to finer spatial scales, are widely preferred for projections of climate change at local and regional scales (Tadross et al. 2011, 28). Two main types of downscaling methodologies may be employed, namely statistical (empirical) and dynamical downscaling. For further explanations of these methodologies, see Tadross et al. (2011, 30).

Downscaled projections are increasingly being used in studies of regional impacts and adaptation, and it is thus critical that the limitations of these data sets are well understood. A key limitation of all downscaling techniques is that their performance is highly dependent on the quality of the input data, and that downscaled data may inherit assumptions and errors in the GCM simulations. Therefore, in order to consider the range of climate change projections, a suite of GCM and downscaled RCM projections should be used in any impact and adaptation assessment. Although downscaled simulations are in theory expected to provide a more accurate description of regional climate and its expected future change, the higher resolution offered by these simulations does not necessarily mean higher confidence in the projections (Tadross et al. 2011, 30).

Key messages from regional climate projections

Climate Risk and Vulnerability Handbook for Southern Africa

The first edition of the Climate Risk and Vulnerability Handbook for Southern Africa (Davis 2011) considered three main sources of climate change projections for Southern Africa: GCMs, statistical downscaling (Hewitson and Crane 2006), and dynamical downscaling (Engelbrecht et al. 2009; Engelbrecht et al. 2013). All the models assumed an A2 SRES emissions scenario and are for the 2036-2065 period relative to the 1961-2000 period. The approach taken in the handbook focused on finding areas of agreement between the three sources of climate change projections for the southern African region, and thus focusing the findings that may form the basis for robust decision making. Overall, there is greater confidence in the magnitude of changes in temperature than in the magnitude of changes in rainfall. The reason for the latter being that projected changes in rainfall vary more between models, due in part to differences in the models' ability to replicate observed rainfall patterns and simulate rainfall producing processes (Stocker et al. 2013).

Box 1 below, taken in part from Tadross et al. (2011, 50), shows key areas of agreement as well as important metadata for the three projection sets, including findings on areas of agreement around extreme weather events (assuming an A2 SRES scenario). GCMs, statistical downscaling and dynamical downscaling all show an increase in projected temperatures, particularly for the interior of the subcontinent. The ensemble of statisticaly downscaled GCMs indicates an increase in temperature of between 0.8°C and 3.6°C per annum. Similarly, the ensemble of dynamically downscaled GCMs indicates an increase in temperature of between 0.4°C and 3.2°C per annum. In addition, all models show increases in very hot days and in heat-waves. This finding is supported in AR4 (Qin et al. 2007), which states that under the A1B and A2 emission scenarios the mean annual temperatures are expected to exceed 2°C over large areas of Southern Africa. Under high RCP, projections indicate that mean annual temperatures could reach between 3°C and 6°C over the region by the end of the century (Stocker et al. 2013).

3 Radiative forcing is a measure of the energy absorbed and retained in the lower atmosphere (Qin et al. 2007).

4 The physical process which produces rainfall in thunderstorms

Despite the differences between the projected change in rainfall derived from the statistical and dynamical downscaling methods presented in the handbook, there are still regions where the ensembles agree. These include increases in annual rainfall over south-east South Africa, decreases in rainfall over southern Zambia and Zimbabwe during summer (December-January-February), and a decrease in rainfall over central Zambia during spring (September-October-November). The finding based on the dynamically downscaled models that rainfall over the south-western region of Southern Africa is expected to decline, is replicated in the AR5 (Stocker et al. 2013). The difference in rainfall projections between the statistical and dynamical downscaling methods may be attributed to the way in which the downscaling methods relate surface rainfall to physical rainfall-producing mechanisms, including the land surface and associated feedbacks.

Box 1

Summary and comparison of climate change projections from the GCMs and the two downscaling techniques (Tadross et al. 2011, 50)

	GCM	Statistical downscaling	Dynamical downscaling
Time scale	1960-2000 2030-2060	1961-2000 2036-2065	1961-2000 2036-2065
Rainfall	Decreases over central and western Southern Africa during summer (December-January-February) and autumn (March-April-May). Increases further north over East Africa. Decreases over most of Southern Africa during spring (September-October-November) and south-west Africa during winter (June-July-August).	Increases over Angola, northern Mozambique and south-east South Africa during summer (December-January-February) and autumn (March-April-May). Decreases over Zimbabwe, Zambia, western Mozambique and parts of the south western coastline during summer (December-January-February) and spring (September-October-November).	Increases over East Africa and south-east South Africa during summer (December-January-February). Decrease in rainfall projected for western Southern Africa in winter (June-July-August).
Temperature	Increase in mean, minimum and maximum temperature		
	1-3°C	0.8-3.6°C	0.4-3.2°C
Extreme weather events	Increase in the amount of very hot days and heat-waves.	Increase in the amount of very hot days and heat-waves.	More extreme rainfall events over eastern Southern Africa Increase in the amount of very hot days – above 35°C.

South Africa's Long Term Adaptation Scenarios (LTAS)

The Long Term Adaptation Scenarios (LTAS) is a policy-relevant research programme lead by the Department of Environmental Affairs in South Africa in collaboration with the South African National Biodiversity Institute. It aims to respond to the South African National Climate Change Response White Paper (Republic of South Africa 2011) by investigating the socio-economic and environmental impacts of climate variability and change, and by developing suitable adaptation scenarios under plausible climate futures for key sectors in South Africa (Department of Environmental Affairs 2013).

The LTAS Technical Working Group on Climate Scenarios developed four climate change scenarios for South Africa, namely (Department of Environmental Affairs 2013, 18):

1. Warmer and wetter
2. Warmer and drier
3. Hotter and wetter
4. Hotter and drier

'Warmer' is considered to be less than 3°C above the 1961-2000 baseline average, while 'hotter' is defined as more than 3°C above the 1961-2000 baseline average. In terms of rainfall, 'drier' considers a future with an increased frequency of drought events and slightly greater frequency of extreme rainfall events. In contrast, 'wetter' defines a future with significantly greater frequency of extreme rainfall events (Department of Environmental Affairs 2013). These four scenarios provide a substantial contribution to the working messages on projected climate change for South Africa.

Dynamically downscaled projections

A set of six climate simulations has been performed by the Climate Studies, Modelling and Environmental Health Research Group of the Council for Scientific and Industrial Research (CSIR) in South Africa. In these experiments, a variable-resolution atmospheric global circulation model (AGCM) was applied as a regional climate model (RCM) to simulate both present-day and future climate over Southern Africa and its surrounding oceans. The AGCM used to perform the downscalings is the conformal-cubic atmospheric model (CCAM) of the Commonwealth Scientific and Industrial Research Council (CSIRO) in Australia (McGregor 2005). Earlier climate projection studies using CCAM over Southern Africa, including verification of the model's ability to simulate present-day Southern African climate, are described by Engelbrecht et al. (2009; 2013) and Malherbe et al. (2013).

The following section presents projections of temperature and rainfall for Southern Africa obtained from dynamical downscaling techniques. The change is expressed as an anomaly, the difference between the average climate over a period of the last several decades (1971-2000), and the projected climate (near-future 2015-2035, mid-future 2040-2060, far-future 2080-2100). For temperature, the 10^{th}, 50^{th} (median) and 90^{th} percentiles are shown for each time period in order to present the ensemble of projected changes. For rainfall, the focus is on the spatial patterns of change which are identified in the median (50^{th} percentile) downscaled GCM response in order to identify regions where change is most consistently simulated by the ensemble of six dynamically downscaled GCMs. The projected changes are based on outputs from IPCC AR4 (A2 SRES emissions scenario) and IPCC AR5 (RCP 8.5 and 4.5 Wm^{-2} pathways). The A2 emissions scenario assumes that society will continue to use fossil fuels at a moderate growth rate, that there will be less economic integration, and that populations will continue to expand (Nakicenovic et al. 2000). RCP 4.5 describes a future with relatively ambitious emission reductions, whereas RCP 8.5 describes a future with no reductions in emissions. Emissions in RCP 4.5 peak around 2040, then decline; in RCP 8.5 emissions continue to rise throughout the 21st century (Meinshausen et al. 2011; Stocker et al. 2013).

Temperature

Temperatures over Southern Africa are expected to increase most notably over the central interior of the region, with smaller increases over coastal areas. Under the A2 emission scenario, temperature increases of 1-2°C are projected for the near future, and for the far future, increases of more than 4°C are plausible for over the central interior (Figure 1). In general, winter and summer show the greatest increase in temperature. Substantially smaller increases in temperature are projected for RCP4.5 compared to the A2 and RCP8.5 scenarios (Figures 2 and 3). The most drastic rise in temperature is projected for the RCP 8.5 scenario with increases of 5-7°C across the interior, and more than 3°C for the coastal areas by the end of the century (2080-2100).

Rainfall

Under the A2 emission scenario, a drying signal is observed over Namibia and Angola, extending south-eastwards to Zambia, Zimbabwe, Botswana, the southern region of Mozambique, and Limpopo province of South Africa (Figure 4). The amplitudes of the projected changes differ somewhat for the far and mid-future compared with the near future. These decreases in rainfall are projected to occur most strongly in summer, which is the main rainfall season for these regions (Figure 5). This drying trend is expected to increase over time as a result of increases in the occurrence of mid-level highs over the eastern parts of Southern Africa, a strengthening of the Indian Ocean High to the southeast of the subcontinent, and an associated northward displacement of tropical lows and cyclones (Engelbrecht et al. 2009; Malherbe et al. 2013). Significantly drier winters are projected for the south-western Cape of South Africa and are consistent with the projected poleward shift of the Westerlies and mid-latitude cyclones (Tennant and Reason 2005; Stager et al. 2012). This drying trend over the south-western Cape is also projected under the RCP 4.5 and 8.5 scenarios (Figure 4). There is a difference between the A2 and RCP scenarios, with wetting projected over Namibia (under RCP 4.5 and 8.5), northern interior of South Africa, and some parts of Botswana and Angola (under RCP 4.5).

Despite predictions of general drying conditions over most of Southern Africa, slight to moderate rainfall increases are projected over the central interior and south-eastern parts of South Africa, west coast of Madagascar, Tanzania, eastern DRC, and northern region of Mozambique for the near and mid-future time period. These increases in rainfall are projected to occur in spring and summer. Engelbrecht et al. (2009) attribute these changes to the deepening of the heat low over the western interior during spring and summer seasons. A heat low is a shallow low-pressure system that develops in response to strong heating of the earth's surface and is conducive to thunderstorm formation.

Extreme weather events

There is a tendency toward an increase in intensity of rainfall (extreme events) which is also linked to the strong heating of the earth's surface. A general increase in the frequency of extreme rainfall events (20 mm of rain falling within 24 hours) is likely to occur over the eastern parts of the continent and the western parts of Madagascar (Figure 6). The increasing signal amplifies toward the end of the century (2080-2100). This increase is partially driven by changes in the landfall of tropical cyclones originating in the Indian Ocean. Over the rest of the region the future trend in extreme rainfall is inconsistent, with reductions expected over the interior of the continent and most notably over the eastern half of South Africa. Changes in thunderstorms

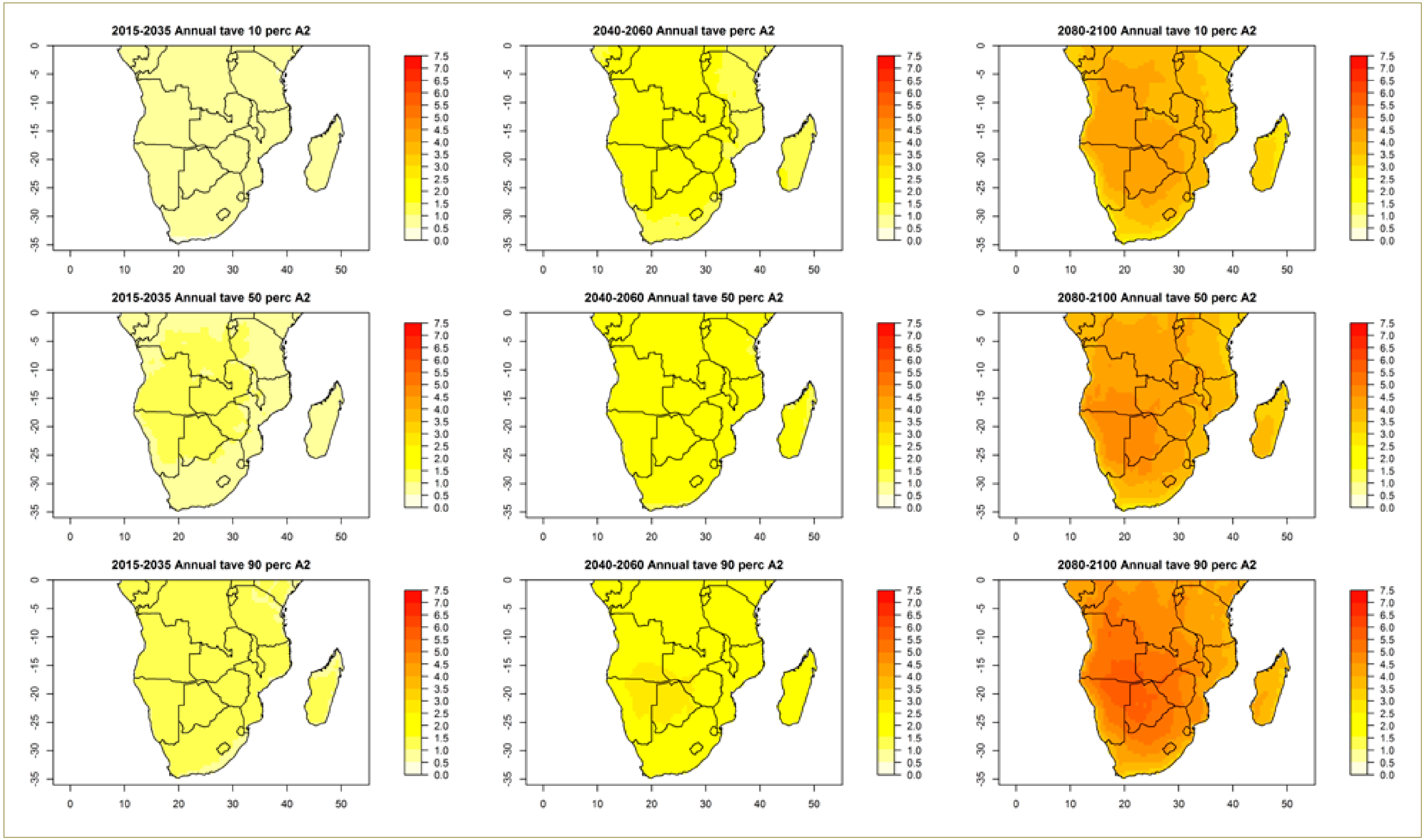

Figure 1. Projected change in average temperature over Southern Africa for the time periods 2015-2035, 2040-2060 and 2080-2100, relative to 1970-2000. Units are the change in the temperature (°C) per grid point per year based on the 10th percentile (left), median (middle), and 90th percentile (right) of six CCAM downscalings under the A2 emission scenario.

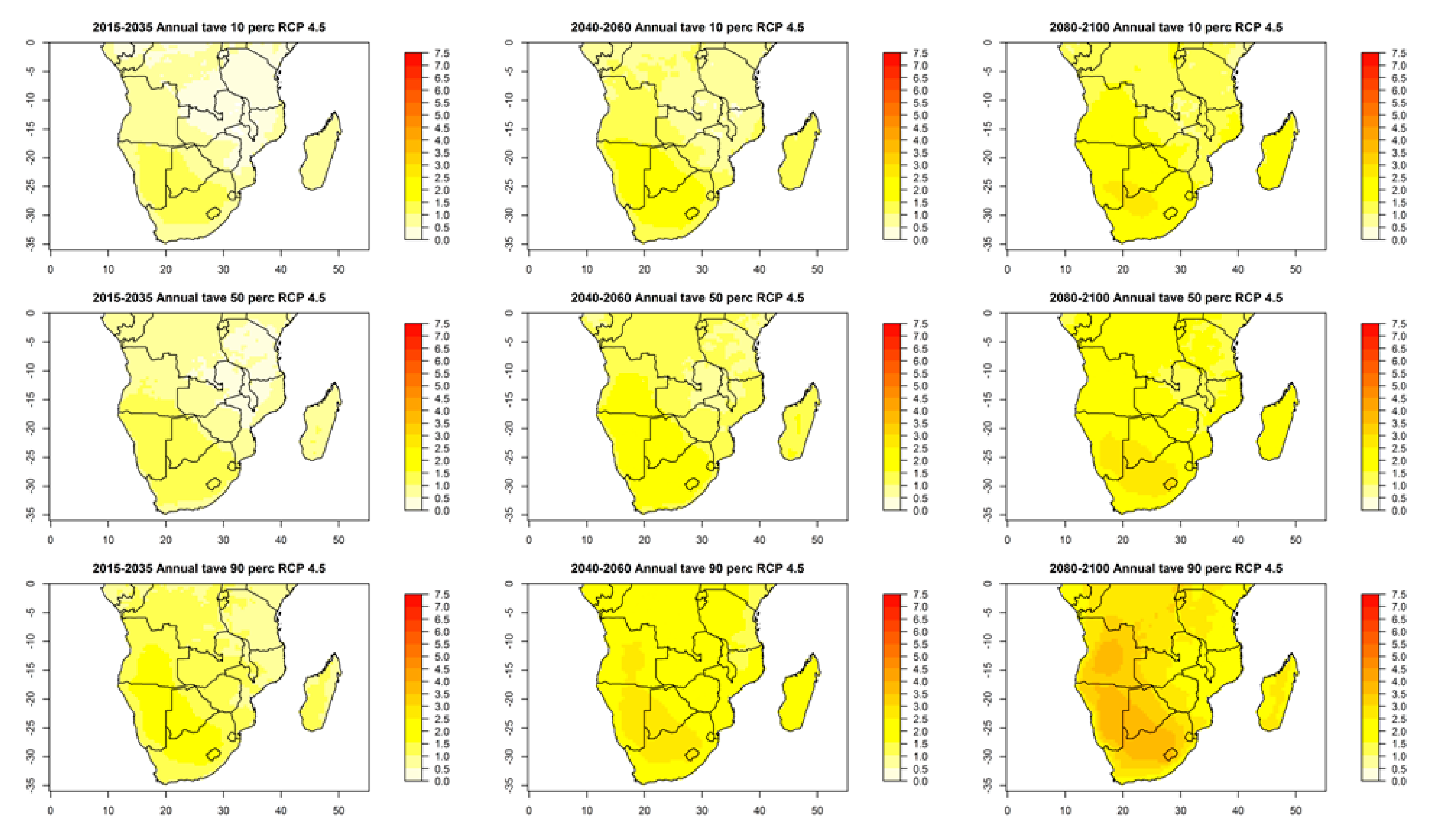

Figure 2. Projected change in average temperature over Southern Africa for the time periods 2015-2035, 2040-2060 and 2080-2100, relative to 1970-2000. Units are the change in the temperature (°C) per grid point per year based on the 10th percentile (left), median (middle), and 90th percentile (right) of six CCAM downscalings under RCP 4.5.

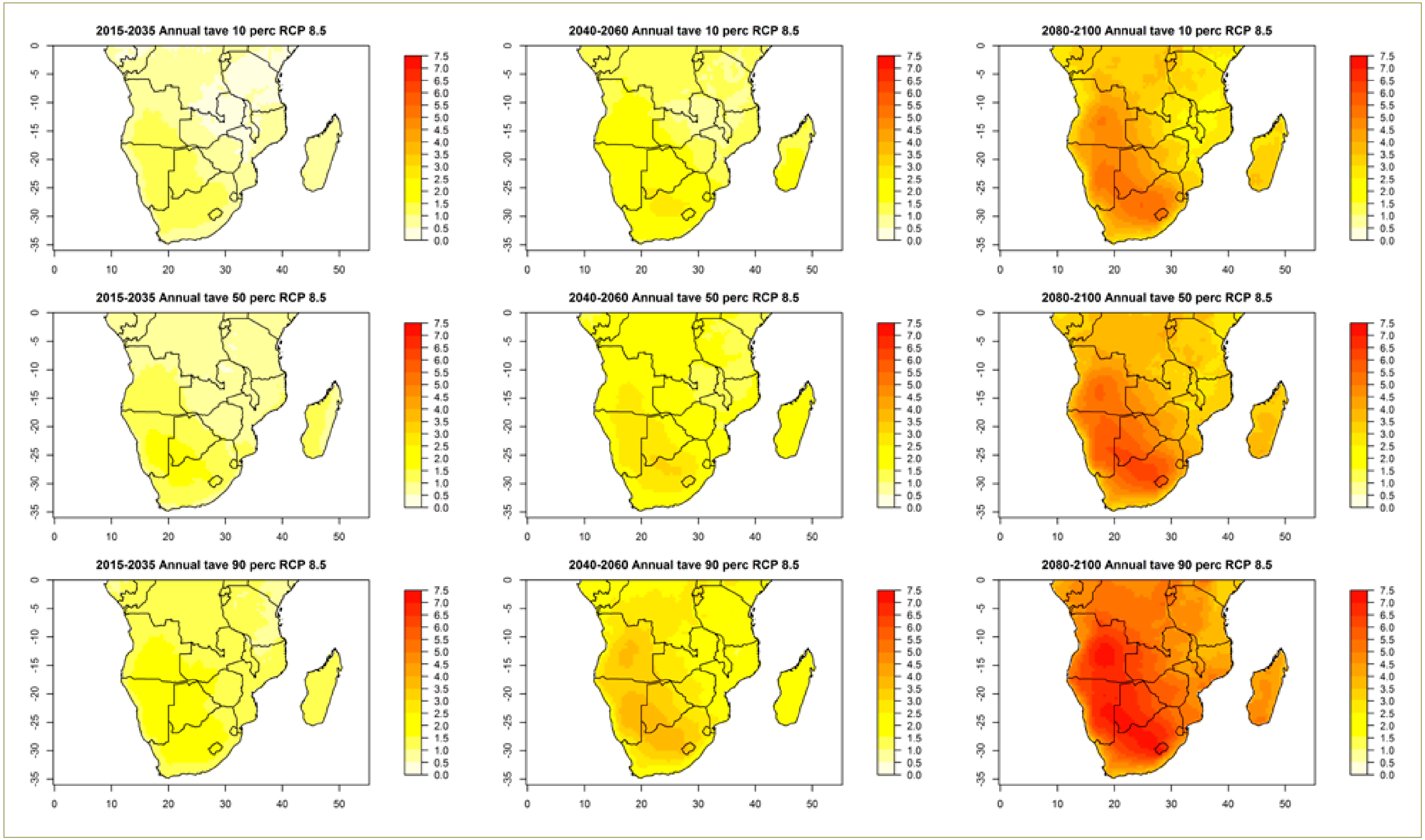

Figure 3. Projected change in average temperature over Southern Africa for the time periods 2015-2035, 2040-2060 and 2080-2100, relative to 1970-2000. Units are the change in the temperature (°C) per grid point per year based on the 10th percentile (left), median (middle), and 90th percentile (right) of six CCAM downscalings under RCP 8.5.

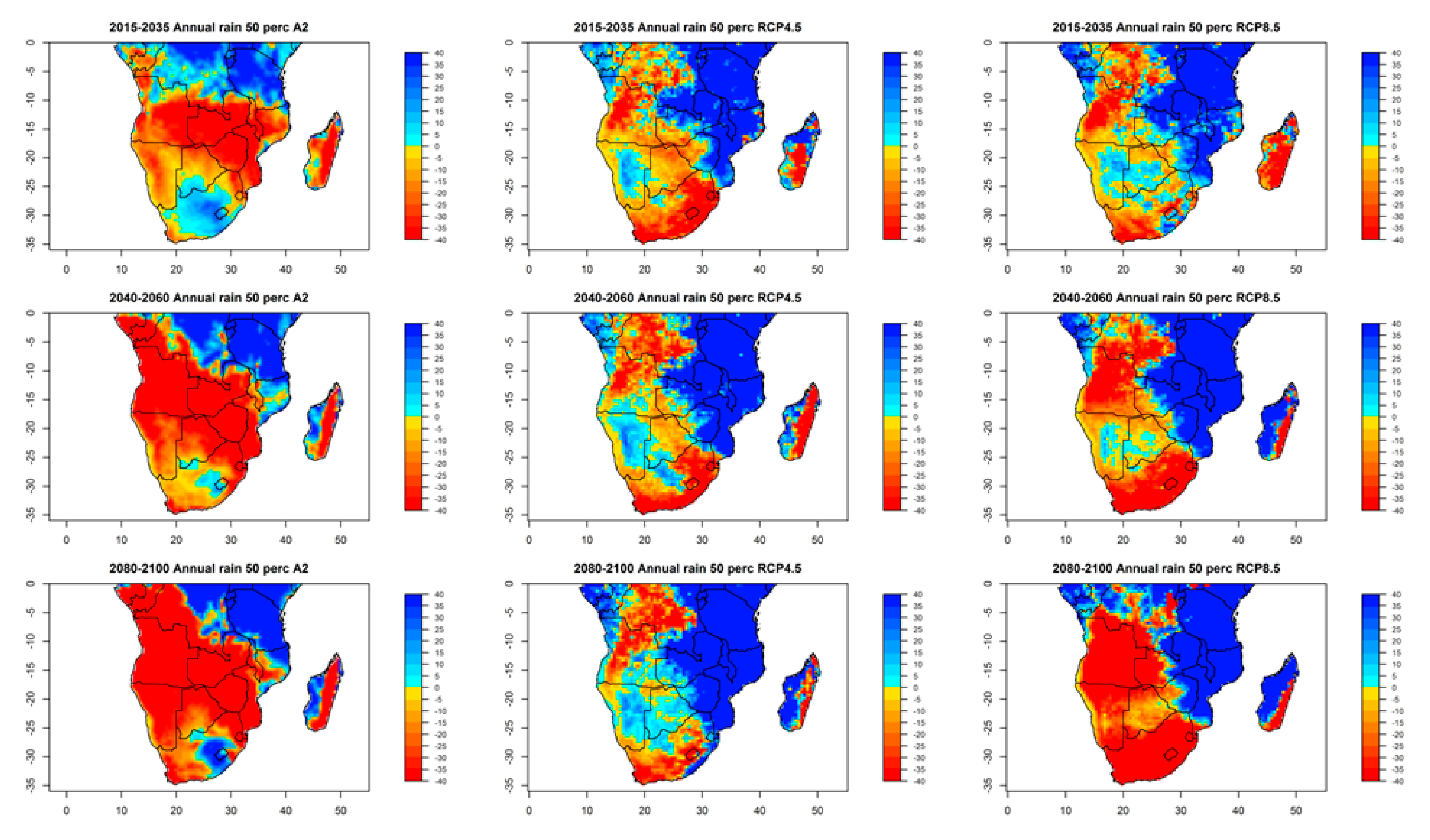

Figure 4. Projected change in the average annual rainfall (mm) over Southern Africa for the time periods 2015-2035, 2040-2060 and 2080-2100, relative to 1970-2000. Units are the change in the amount of rainfall (mm) per grid point per year based on the median of six CCAM downscalings under A2 (left), RCP 4.5 (middle), and RCP 8.5 (right) scenarios.

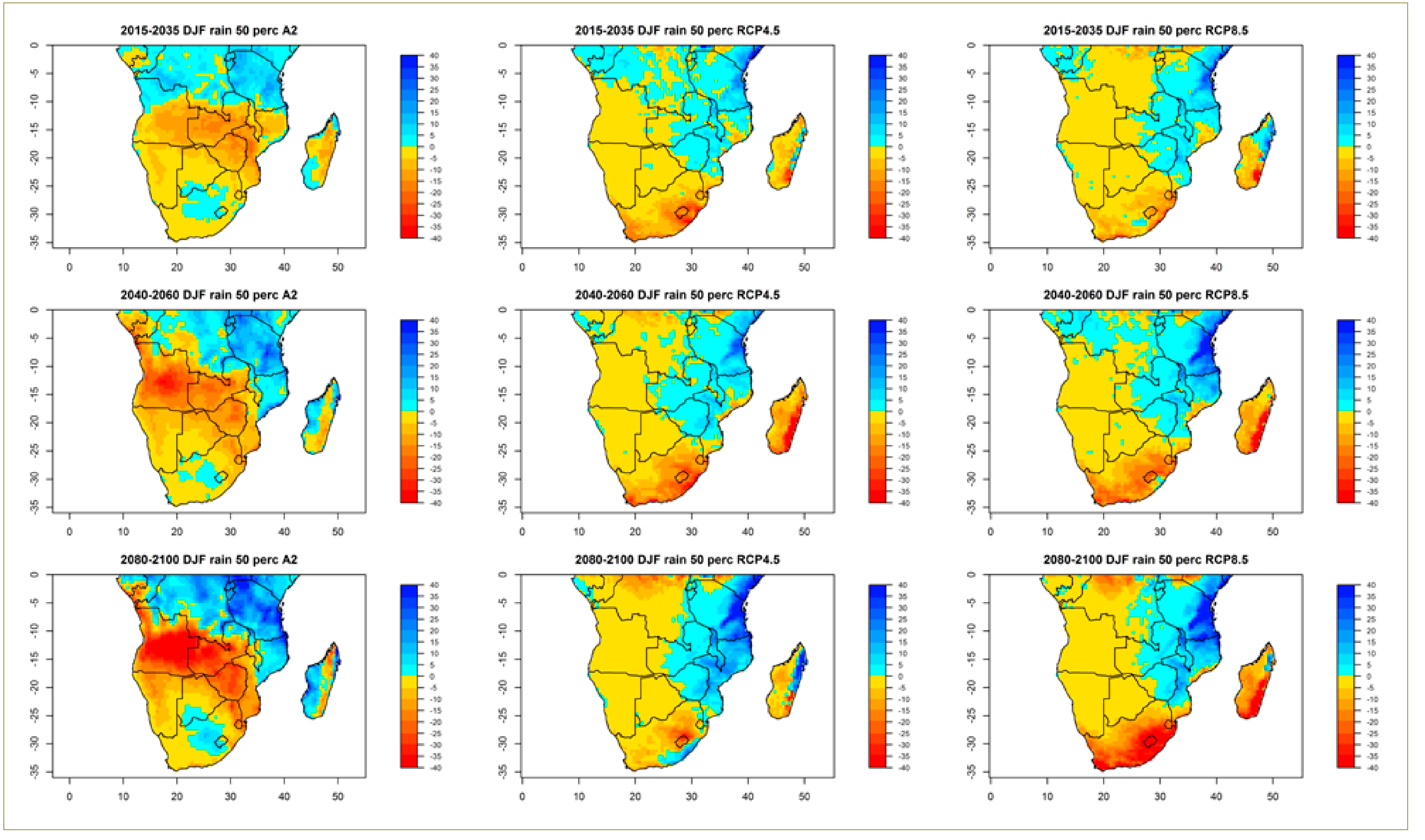

Figure 5. Projected changes in the average seasonal rainfall (mm) over Southern Africa for December-January-February (DJF) for the time periods 2015-2035, 2040-2060 and 2080-2100, relative to 1970-2000. Units are the change in the amount of rainfall (mm) per grid point per year based on the median of six CCAM downscalings under A2 (left), RCP 4.5 (middle), and RCP 8.5 (right) scenarios.

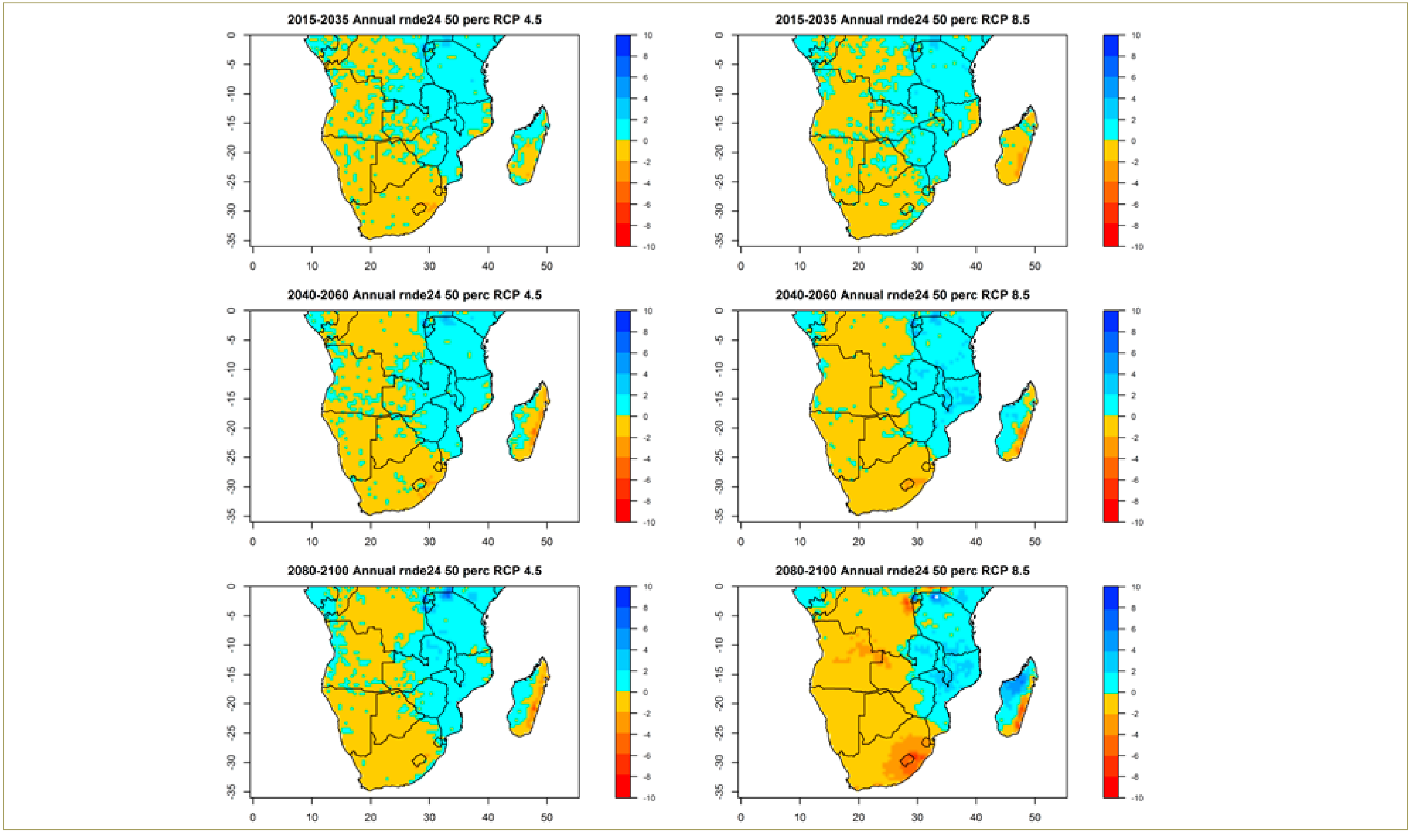

Figure 6. Projected change in the number extreme rainfall days (20 mm of rain falling within 24 hours) over Southern Africa for the time periods 2015-2035, 2040-2060 and 2080-2100, relative to 1970-2005. Units are the change in the amount of rainfall (mm) per grid point per year based on the median of six CCAM downscalings under RCP 4.5 (left) and RCP 8.5 (right) scenario.

(including hail and lightning) are difficult to detect due to insufficient studies and data issues, and there is low confidence in the observed trends and future projections (Stocker et al. 2013).

There is little evidence to suggest long-term changes in tropical cyclones (intensity, frequency and duration) (Stocker et al. 2013; IPCC 2012). Tropical cyclones are very difficult to simulate even under current climatic conditions, and there are large uncertainties on projected changes (Stocker et al. 2013). The general increase in temperature and water vapour, however, suggest an upsurge in tropical storms and cyclones over the southwest Indian Ocean. Further research is needed in order to better project changes in the characteristics of tropical cyclones occurring over the latter area (Malherbe et al. 2013; Tadross et al. 2011).

Coastal storm surges are expected to increase due to sea level rise and an increase in the frequency and intensity of sea storms, accompanied by increases in wave heights (Stocker et al. 2013). Even if the intensity of sea storms remains unchanged, higher sea levels will mean that smaller storms are likely to have an increased impact on the coastline (Theron 2011).

South Africa is projected to become warmer, and the increase in average temperature is projected to occur in association with an increase in the number very hot days (number of days when the maximum temperature exceeds 35°C) and heat wave events (Figure 7). The occurrence of fires is closely linked with climate, and increases in temperature, combined with an increase in dry spells in some areas, may result in wildfires affecting larger areas and may result in fires of higher intensity and severity (IPCC 2012). Low temperatures, including the number of frost days, have decreased in frequency and are expected to become less frequent in the future (DEA 2013).

Comparisons between GCMs, statistically and dynamically downscaled projections for different RCPs

The following results are taken from a study to assess the spread of possible future climates simulated by a multi-model and multi-method hyper ensemble (Hewitson et al. 2014). The simulated climates are taken from an ensemble of sixteen GCMs, an ensemble of statistical downscaling of ten of these GCMs, and an ensemble of a single RCM downscaling of eight GCMs generated through the CORDEX[5] framework. All simulations utilised both the RCP 4.5 and 8.5 scenarios, and while some of the RCM downscalings used GCMs not included in the GCM ensemble, these model future climates remain valid.

Figure 8 indicates the future changes (2041-2070 period relative to 1976-2005 period) in December-January-February (DJF) rainfall and temperature simulated by the different ensembles, the RCP scenario as a whole, and the individual ensemble members, averaged over Southern Africa. For rainfall, the medians for each ensemble and scenario indicate a reduction in rainfall, but it can be seen that some of the individual ensemble members (particularly in the GCM ensemble) simulate an increase in rainfall. Without further information on how these models simulate the regional climate, it is difficult to assess how representative they may be and we must assume they are equally plausible representations of the future climate. However, taking the interquartile ranges as an indication of what may be the most likely future, would suggest a reduction in rainfall. For maximum temperatures, all scenarios, ensemble medians and individual models suggest an increase in the future. The GCM ensemble again encompasses the range of simulations in the statistical and dynamically downscaled ensembles, with the exception of two dynamical downscalings of the RCP 4.5 scenario. Nevertheless, taking the interquartile ranges, the hyper ensemble suggests increases in maximum temperatures of between 1°C and 3°C.

Figure 9 shows maps of median simulated changes in seasonal (DJF) rainfall in each of the three ensembles for the RCP 8.5 scenario. The GCM ensemble change is shown for the same 10 GCMs used for the statistical downscaling. While there are some regional differences in simulated rainfall between the different ensembles, there are clearly also areas of convergence. The median of the GCM ensemble indicates drying over much of the region south of the latitude 15S, with mostly wetting further north. The statistical downscaling ensemble indicates a similar drying region (mostly concentrated in a band across central Southern Africa extending further north), whereas the dynamical downscaling ensemble has a tendency for more extreme drying over central and south-eastern Southern Africa, with wetting towards the southwest. Central Southern Africa (e.g. northern Botswana/Namibia, southern Zambia, and Zimbabwe) is consistently projected to be drier in all three ensembles, with Tanzania and parts of northern Mozambique projected to be wetter in the future. It is notable that these regions of consistent drier/wetter modelled changes are also consistent with the results simulated for DJF by CCAM under an assumed A2 scenario, suggesting

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the simulated changes are robust under a wide range of modelling approaches. Differences between the three ensembles below, however, serve as a reminder that simulated changes in some regions may be dependent on both the GCMs used to make an assessment, as well as the method for producing the rainfall estimates.

Conclusion

As stated earlier, projected changes in rainfall for the long-term presented in this chapter may on occasion disagree (e.g. rainfall) or be consistent (e.g. temperature) – depending on the method or model used. The difference in rainfall projections between statistical and dynamical downscaling ensembles may be attributed to the way in which surface rainfall is related to the physical processes which produce rainfall, as well as the choice of GCMs used in the downscaling ensemble. Even so, here we find greater consistency between projections using different modelling approaches than was found in earlier work (Tadross et al. 2011), suggesting that convergence may be enhanced through the use of more GCMs and through refinement/development of modelling approaches and downscaling tools. Assuming that emissions of anthropogenic greenhouse gases continue rising at current or higher levels, central Southern Africa is highlighted as a region likely to be drier in the future during mid-summer, with parts of Tanzania likely to be wetter. As a robust finding, temperatures are projected to further increase into the 21st century. Warming is likely to be greatest towards the interior, and less in coastal areas – a finding consistent with earlier results for the region. Decreases in mid-summer rainfall, together with higher temperatures, will have critical implications for water availability and will impact a number of sectors, particularly agriculture and hydrology in regions that are already considered vulnerable.

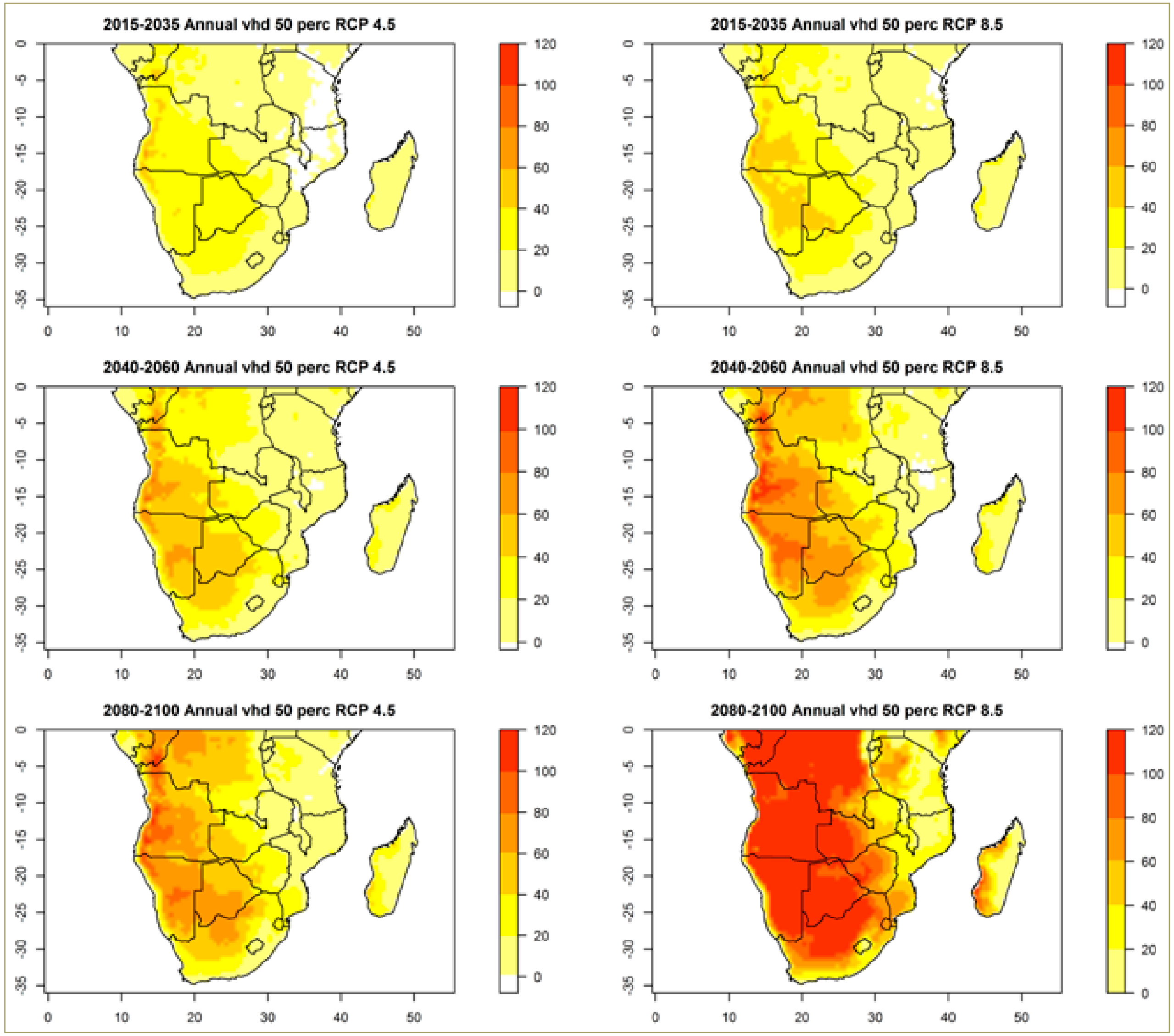

Figure 7. Projected change in the number hot days (above 35°C) over Southern Africa for the time periods 2015-2035, 2040-2060 and 2080-2100, relative to 1970-2005. Units are the change in the amount of rainfall (mm) per grid point per year based on the median of six CCAM downscalings under RCP 4.5 (left) and RCP 8.5 (right) scenario.

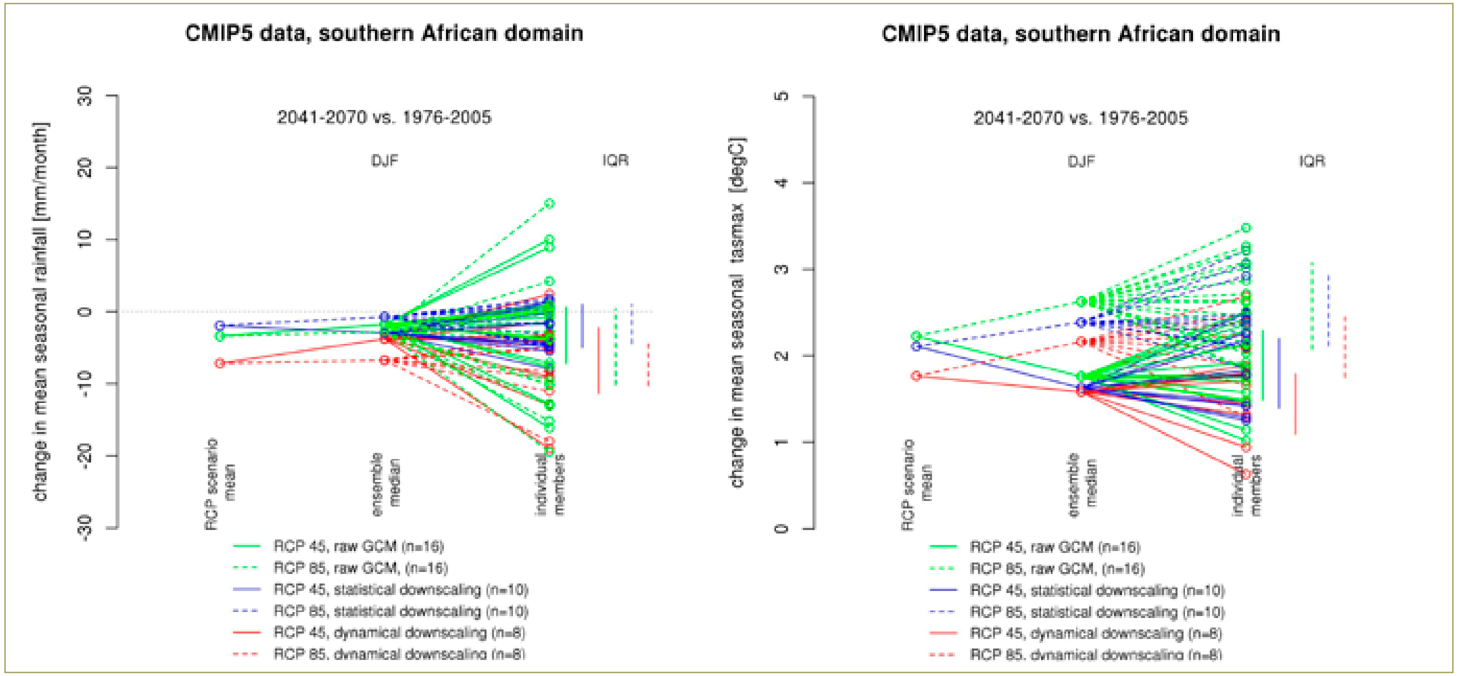

Figure 8. Change in mean monthly rainfall (left) and maximum temperature (right) for DJF for two RCP scenarios: Sixteen GCMs, ten statistical downscaling realisations, and eight regional climate model realisations averaged over the domain covering the land body of Southern Africa (35°-20°S, 10°-40°E). Bars on the right-hand side of the graphs mark the interquartile range for each ensemble/RCP combination.

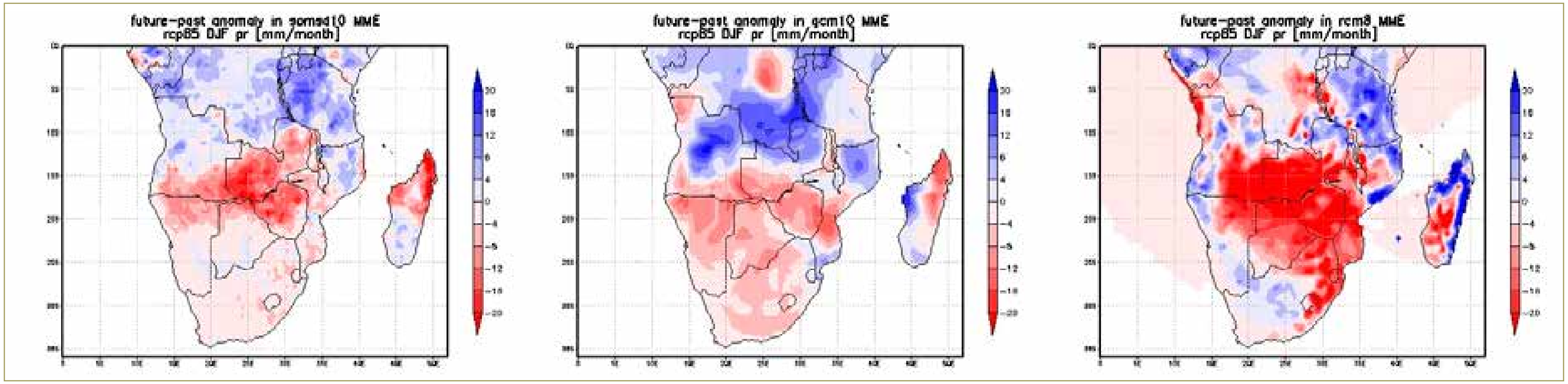

Figure 9. Maps of ensemble median of change in rainfall (2041-2070 period relative to 1976-2005 period), in statistically downscaled ensemble (left), GCM ensemble (middle), and dynamically downscaled ensemble (right), for DJF under RCP 4.5.

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