Climate Change Scenarios for the Limpopo River Basin

Consolidated Report

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Contents

List of Abbreviations

Abbreviation	Full name
CMIP	Coupled Model Intercomparison Project Phase
CSDI	Cold Spell Duration Indices
IAV	Inter-annual variability
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
LIMCOM	Limpopo Watercourse Commission
RCPs	Representative Concentration Pathways
RCPs	Representative Concentration Pathways
RLE	Run Length Encoding
SOMS	Self-Organising Maps
TRMM	Tropical Rainfall Measuring Mission
UNFCCC	United Nations Framework Convention on Climate Change
WSDI	Warm Spell Duration Indices

Summary

The approach of self-organising maps (soms) has been used to identify the most prominent pathways of future annual climate change as projected by all CMIP5 climate models for four Domains of the Limpopo River Basin. One Domain covers inflow to the main river channel north-west of the Waterberg in South Africa, a second inflows in the vicinity of the Botswana-Zimbabwe-South Africa borders, a third inflows from the Mpumalanga area in South Africa, and the fourth inflows in the Changane Basin within Mozambique. In addition to employing soms, an analysis has been made of inter-annual variability (IAV) of projected future annual temperatures, rainfall, and rainfall less evaporation, for extended two- and three-year periods based on estimates from historic model simulations of 2 and 3 standard deviations (for temperatures) and 10th, 25th, 75th and 90th percentiles (for rainfall and for rainfall less evaporation).

Temperatures may be expected to increase through the century, more so, of course, for the higher RCPs (Representative Concentration Pathways – the future emissions scenarios used by the IPCC to create the CMIP5 data set). By the latter few decades of the century there may be near-certainty of extended periods of hot weather unless emissions are held to satisfy the UNFCCC Paris Agreement.

In all Domains there are indications that annual rainfall distributions will become more spread, mainly through increases in the frequencies of drier spells. The soms analyses produce prominent pathways covering both increases and decreases in rainfall, with higher likelihoods of increased rainfall in the western two Domains and of decreases in the eastern two. The range for rainfall changes in all Domains within the recommended scenarios is from about -15% over the Botswana-Zimbabwe-South Africa border area to about +10% across the Changane Basin, a little higher should RCP8.5 prove to be closest to reality and rather higher in possible extreme scenarios. In all cases the recommended scenarios include both increased and decreased rainfall.

Parallel rainfall less evaporation analyses suggest the higher likelihoods are for future decreases in all but the westernmost parts of the Basin. Note that the analyses for rainfall less evaporation are a little less stable than those for rainfall alone.

1 Outline of the report and methodology

Various approaches to creating climate change scenarios for specific areas are available based on projections using global coupled climate models, summarised together with discussion of certain of the issues involved in Appendix 1. Certain of the background issues discussed in Appendix 1 are assumed in the following.

The objective within this report is to provide reasonable and representative climate change scenarios for four areas within the Limpopo Basin as a contribution to the LIMCOM Project (Fig. 1).

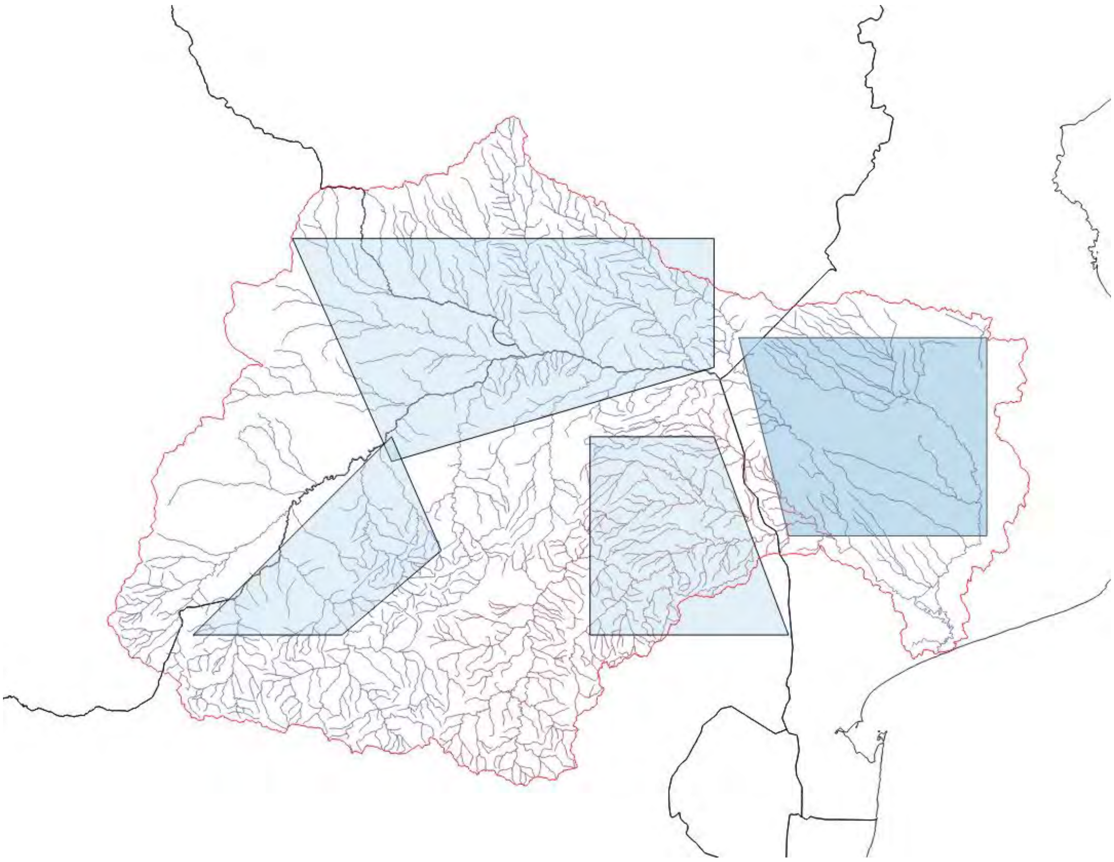


Figure 1. The four regions in the Limpopo Basin for which climate change scenarios have been developed overlaid on the distribution of sub-catchments within the Basin. The regions have been named after some of the major tributaries within each: covering much of the headwaters within South Africa is the Waterberg Domain; that including parts of Botswana, Zimbabwe and South Africa is the ZimBota Domain; that in eastern South Africa is the Mpumalanga Domain; while that in Mozambique is the Changane Domain.

The areas shown in Figure 1 have been based on a combination of climatological and hydrological considerations for this IWRM project. Climate scenarios have been developed using an approach referred to as soms, described in more detail below. The technique of soms is best applied to areas over which the rainfall climatology remains relatively consistent in terms both of amounts and seasonality. In practice this means that any areas to be used need to be appropriately sized (a single analysis over the full Limpopo Basin would likely hide important details), each with reasonably consistent cross-area annual totals and seasonal cycles.

Annual rainfall across the entire Basin is illustrated in Figure 2, and is discussed in more detail in Section 2 following.

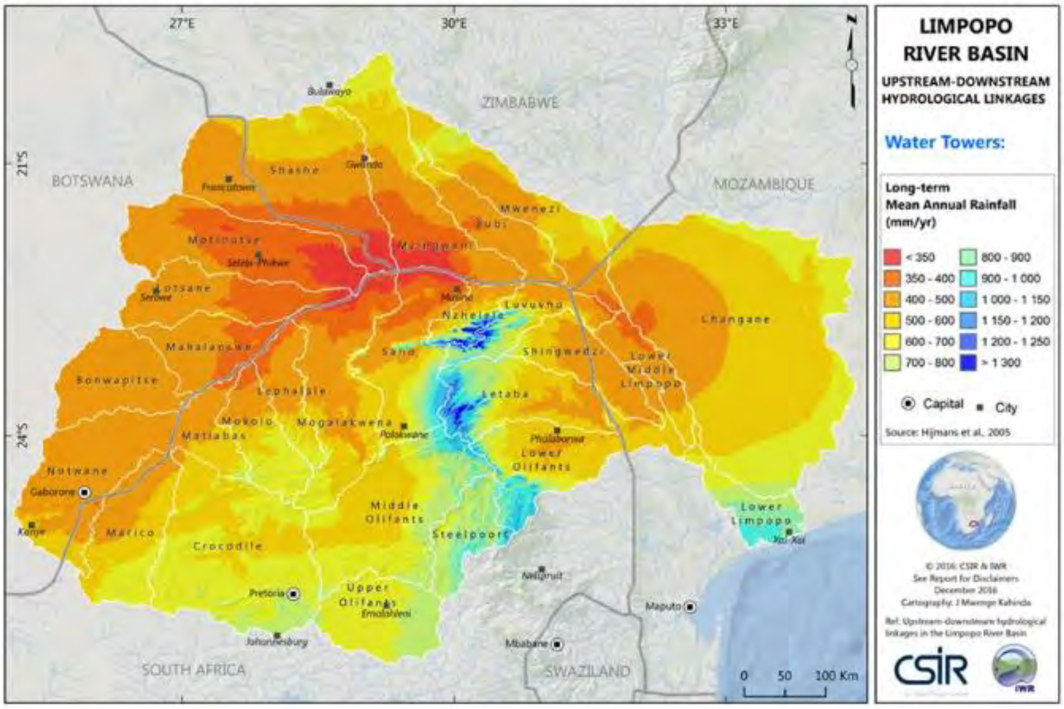


Figure 2. Average annual rainfall over the Limpopo Basin esimated from 1970-200 data at 1km resolutions, from Figure 3.3 of KKOMHH.

Most of the main river channel is semi-arid, or even arid, with average totals below 500mm. The main water towers lie across the Drakensberg and Soutpansberg ranges within South Africa (covered by blue colours in Figure 1), where annual values can exceed 1300m, with Limpopo tributaries flowing towards the east, west and north of these towers. With the entire Basin subject to a marked annual rainfall cycle, with rainfall restricted mainly to summer (chiefly November to March) with little in winter, the peak of the annual cycle tends to move a little later over more western parts (see also Figure 2 following). In general areas of higher rainfall other than the water towers tend to lie along the flanks of the Basin, further south-west in South Africa, over the higher central interior parts of Zimbabwe, and across the east of the Changane Basin in Mozambique. This annual rainfall distribution is of interest as the river forms a valley between South Africa and Zimbabwe with rising land both north and south, creating a channel for moisture to reach the interior during summer with moist easterly winds from the Indian Ocean. Yet the main river channel itself lies within a rainfall minimum. One explanation is that lift resulting from up-slope flow from the main valley provides a stimulus to thunderstorm development, and hence greater falls away from the river. An alternative, but as far as is known unexplored, explanation is that the tropical-temperate troughs, or cloud bands, that provide the bulk of the rainfall, have been noted to form less frequently over the valley in this South Africa-Zimbabwe border region than to either side, something almost certainly related to the larger-scale dynamics of the local atmosphere than to relatively simple up-slope flow.

Hence the Basin includes a number of areas with differing climatological characteristics that have been captured as reasonably as possible through four Domains used in the soms calculations. All Domains have been designed to avoid the steeper and higher mountainous parts, as climate model performance tends to degrade over such areas:

- The Waterberg Domain captures details of climate in some of the western part of the Basin
  - Topographically the land falls steadily towards the west from the Highveld and the Waterberg in South Africa, with slightly increased elevations above the Basin in Botswana
  - Climatologically the Domain covers parts of the higher rainfall area important for flow in the upper reaches of the Basin

- Hydrologically the main inputs to the Limpopo system within this Domain, according to RA[1], are the Crocodile, Mogalakwena, and to a lesser extent, Marico Rivers (although the Mogalakwena itself discharges into the Limpopo in the ZimBota Domain – see below)
    - Rivers in Botswana have not been covered as their discharge is relatively minimal.
- The ZimBota Domain captures details of climate in the three-countries border areas of Botswana, South Africa and Zimbabwe
    - Topographically the land rises on either side of the river, particularly in Zimbabwe and towards the Soutpansberg in South Africa
    - Climatologically the Domain covers the driest areas of the Basin without impinging on the slightly differing climatologies of the higher rainfall regions of the Soutpansberg and central Zimbabwe; nevertheless, results for this Domain are likely to provide valid information also for these latter areas
    - Hydrologically the Domain covers the inflow of the Mogalakwena, plus other major inflows which, according to RA[1], include those from the Sashe, Mzingwane and Sand Rivers
- The Mpimalanga Domain captures details of climate over South Africa east of the Highveld region
    - Topographically the land gets lower towards the east, but non-uniformly with the descent interrupted by mountain ranges and plateau edges
    - Climatologically this Domain includes runoff from the water tower region of the Drakensberg, and covers the main rainfall areas feeding east-flowing rivers
    - Hydrologically the Domain covers some of the highest discharging rivers within the Basin according to RA[1], including the Olifants, Letaba and Shingwedzi Rivers
- The Changane Domain captures details of climate over the main Mozambique part of the Basin
    - Topographically most of the land is relatively flat, but is bound on east and west by mountain ranges
    - Climatologically it is relatively dry, except along the flanks of the eastern mountain range, but it the area within the Basin most susceptible to intrusion by tropical cyclones
    - Hydrologically there is only a single, multi-channel basin, that of the Changane itself, but this provides a significant discharge into the Limpopo according to RA[1].

The approach used is self-organising maps (soms) basic details of which are outlined in Appendix 2. SOMs enable pathways to be identified within the multiple climate change projections available in a way that makes no assumptions concerning any statistical distributions. The most recent, comprehensive set of projections is that within the CMIP5 data set, used as the basis of the WGI (Science) report to the IPCC AR5 of 2013; a new data set of projections, CMIP6, which will provide input into the forthcoming IPCC AR6, is becoming available at the time of writing.

Behind the CMIP5 projections are four scenarios describing possible future pathways of the radiation balance in the atmosphere, pathways directly connected to increasing atmospheric emissions and hence concentrations of carbon dioxide (CO_2), the main driver of climate change. These radiation balance scenarios, defined from pure scientific perspectives, replaced earlier scenarios used by the IPCC, in reports prior to the AR5, constructed using economic and social scenarios (see Appendix 3); further developments have been made in CMIP6 to reintroduce economic and social considerations to the radiation balance scenarios.

There are four radiation balance scenarios, known as Representative Concentration Pathways, or RCPs: RCP2.6, RCP4.5, RCP6.0 and RCP8.5, higher numbers indicating increasing radiative forcing of the climate system from successively greater atmospheric CO_2 concentrations. In order to retain maximum intercomparison between the CMIP5 projections and those in the earlier data set used as a basis of the IPCC AR4 (CMIP3) more projections have been developed for RCP4.5 and RCP8.5 than for the other two.

1 RA: http://www.limpopo.riverawarenesskit.org/LIMPOPORAK_COM/EN/RIVER/HYDROLOGY/HYDROLOGY_OF_THE_LIMPOPO/SURFACE_WATER.HTM

All available projections for all RCPs have been used to develop the scenarios in this report, with particular focus advised to RCP2.6, as the only one offering reasonable opportunity for meeting the Paris Agreement target of 2ºC, never mind the preferred target of 1.5ºC, and to RCP6.0, perhaps a more reasonable high scenario than RCP8.5 given plateauing of global CO_2 emissions in some recent years. This is despite the relatively low numbers of projections in these scenarios, and hence reduced statistical stability in the results, as compared to RCP4.5 and RCP8.5. However it might be noted that the latest information for 2017 indicates that emissions for this year have increased by 1.6% while a recent projection from the Global Carbon Project suggests this will rise to 2.7% in 2018; whether this is the start of a new upwards trend or merely some form of blip is unknown but it does indicate that attention to RCP8.5 cannot be dropped entirely at present, and this would become more realistic if climate sensitivity were higher than expected.

The CMIP data sets are created on an open submission basis, projections being accepted from any source provided the models used perform at least according to certain minimum criteria. There is no attempt to provide a balanced set of projections, as can be developed with a similar approach for predictions on shorter time scales, but the CMIP sets nevertheless represent the optimal, state-of-the-art, information available at any time. SOMs have been calculated for all CMIP5 projections separately for all four RCPs, with scenarios extracted individually for each RCP prior to defining overall recommended scenarios for planning. A brief comparison of the recommended scenarios from this work with those from earlier work for the Limpopo Basin is given later in the Conclusions section.

A new approach to delivering information on projected interannual variability (IAV) has been used within this report to characterise the scenarios in more detail. Various measures of 'extremes' as defined by the IPCC are available for the CMIP5 projections, covering both temperatures and rainfall, although the definitions of the 27 variables indicate a bias towards Northern Hemisphere mid-latitude climates and these are thus less relevant, perhaps, in the Limpopo Basin. Experience in similar work with soms as presented here indicates consistently that there is relatively limited noise in the temperature 'extremes', those projections related to relatively warmer scenarios simulating greater temperature extremes in general than those for relatively cooler scenarios. Details are available on requested, but equivalent and improved information is provided, it is felt, in the IAV statistics.

The IPCC rainfall 'extremes', however, are consistently noisy based on earlier research, with limited uniformity across scenarios, including simply in the directions of any change. Rainfall 'extremes' are therefore not provided directly from the projections in this report in the expectation that these would provide little useful information. Instead statistics have been developed within each sub-period (see below for a definition of the sub-periods) for the complete set of projections. Naturally, rainfall values as simulated within each projection differ substantially, one aspect of the complexity of modelling rainfall. Statistics are presented below for the overall trends in annual rainfall; these statistics thus do not reflect results from any specific projection but illustrate the overall trends within all projections.

The basic temperature/rainfall/evaporation climatologies of each model may differ from observed climatologies and, rather than attempting to correct this directly, the standard approach is to calculate differences from modelled values over a past base period for each projection independently. The base period used here is 1979-2005. This period differs from that used in the IPCC AR5, which is 1986-2005, the same base period used in earlier soms analyses based on CMIP5. The reason is technical, but in the soms results for the Limpopo Basin a statistical instability was uncovered using a base period of 1986-2005 that is reduced significantly by using the longer period of 1979-2005. Future temperatures are calculated as differences in ºC from those averaged over the base period, while future changes in rainfall and in rainfall less evaporation are presented as ratios relative to values in the base period, values above 1.0 indicating increases, values below decreases.

The soms analyses are based on two approaches:

- temperature simulations combined with simulated changes in rainfall
- temperature simulations combined with the simulated differences between rainfall and evaporation, a basic measure of water availability in the Basin (evaporation increases with temperature, a factor taken into consideration in these calculations).

In earlier work using temperature against rainfall less evaporation and the shorter base period of 1986-2005 it was determined that for certain models rainfall roughly equalled evaporation during that base period. As a consequence, ratios of projected values of rainfall less evaporation compared to those during the base period could be unreasonably large, creating a distortion within the soms calculations. After testing various approaches, a simple subjective selection was used to remove projections producing unrealistically high rainfall less evaporation ratios. In the first results for the Limpopo Basin a similar effect was noted for temperature against rainfall alone, although the source of the issue was different to that outlined above. Use of the longer base period of 1979-2005 appears to resolve both issues adequately.

Simulations for projected values averaged across three sub-periods have been used as inputs to the soms analyses, values for all three periods entering each single soms calculation for each RCP as the objective is to identify future pathways through the remainder of the century rather than pathways within each of the three sub-periods. The sub-periods differ a little from those used in earlier reports, although these differences are unlikely to result in substantial changes to the pathways identified. There are two reasons for the change:

- First, time is progressing and some years represented in earlier analyses are now within the recorded period
- Second, in order to undertake the IAV calculations, as long a period as possible is desirable to help stabilise the statistics.

Thus each sub-period is 25 years in length: 2025-2049, 2050-2074 and 2075-2099. In the remainder of the report each sub-period is represented by a single central year, namely 2040, 2065 and 2080; on diagrams the sub-periods may be denoted respectively as P1, P2 and P3.

The methodology employed for creating and interpreting the soms is:

- Preliminary examination of the rainfall climatology (used in defining the area for the soms calculations)
- Brief assessment of basic properties of the CMIP5 projections, based on ensemble means and standard deviations
- Examination of soms for temperature vs rainfall and for temperature vs rainfall less evaporation and development of suggested scenarios for each (see results towards the latter parts of the reports for each Domain)
    - Done separately
    - Each som examined independently to develop the suggested scenarios to ensure, as far as possible, no bias from previous assessments is introduced
    - A brief justification for each set of suggested scenarios added as an *aide memoire*
- Once completed all suggested scenarios collated into an overview section presented immediately after the introduction section in the report for each Domain, and a new summary of these scenarios prepared
- Once all scenarios are collated as above final recommended scenarios, with likelihoods, for each Domain are determined subjectively, together with ‘extreme’ scenarios based on increases and decreases of water availability
- Further details on the recommended scenarios are then provided through study of the IAV results.

The IAV statistics focus on the estimated probabilities for each som that future climate will change to create new periods of either two or three years successively over which annual temperatures may increase by over two or three standard deviations or annual rainfall/rainfall less evaporation values will exceed the 10th and 25th percentiles (for decreases) and the 75th and 90th percentiles (for increases), in all cases calculated across the base period of 1979-2005. Percentiles have been used rather than standard deviations for rainfall and for rainfall less evaporation because of the likelihoods that these distributions are non-Gaussian. IAV charts have been placed in the documents for each Domain immediately following the soms charts to which they refer; the temperature charts from the temperature vs rainfall less evaporation assessments have not been included as, in essence, they are similar to those from the temperature vs rainfall assessments; these charts can be provided if required. Values for RCP2.6 and RCP6.0 tend to be noisier than those for RCP4.5 and RCP8.5 because of the relative paucities of projections. Similar diagrams have been provided for the same IAV statistics calculated for each RCP using all projections.

The background values of standard deviations and percentiles used for IAV have been calculated from annual values as simulated independently by each climate model across the base period, 1979-2005. Probabilities of exceedance have then been calculated as running two- and three-year values across successive decades individually for each model. Mean values of standard deviations or specific percentiles have been added to each diagram as guides (see below for details). This approach has been selected as average temperatures/rainfall totals/rainfall less evaporation values, and their standard deviations/percentiles, as simulated by each model differ quite substantially over the base period, and hence it is not possible to undertake the calculations by simple averaging across all projections (this is also the reason why the soms results are calculated for differences for temperature and for ratios for rainfall and for rainfall less evaporation). It is not possible, therefore, to give an interpretation of the temperature standard deviations and the rainfall/rainfall less evaporation percentiles in absolute terms, but proxy values estimated across the models contributing to each som are provided in each chart to offer a guide.

2 The rainfall climatology of the Limpopo Basin in brief

A recent rainfall climatology for southern Africa is illustrated in Figure 3 derived from the Tropical Rainfall Measuring Mission (TRMM) satellite data. The dry area extending along the Limpopo Basin covering the borders of both Botswana and Zimbabwe with South Africa in all months is readily apparent in these averages. The corresponding “water tower” regions for the Basin are located more towards the edges of the region over the higher areas of South Africa and Zimbabwe. The Mozambique parts of the Basin share similar rainfall amounts to those of the “water towers”. Note that in the early part of the season, until November, highest rainfall occurs south of the Basin itself, largely in relation to temperate systems. Rainfall from tropical systems mainly establishes itself from December onwards.

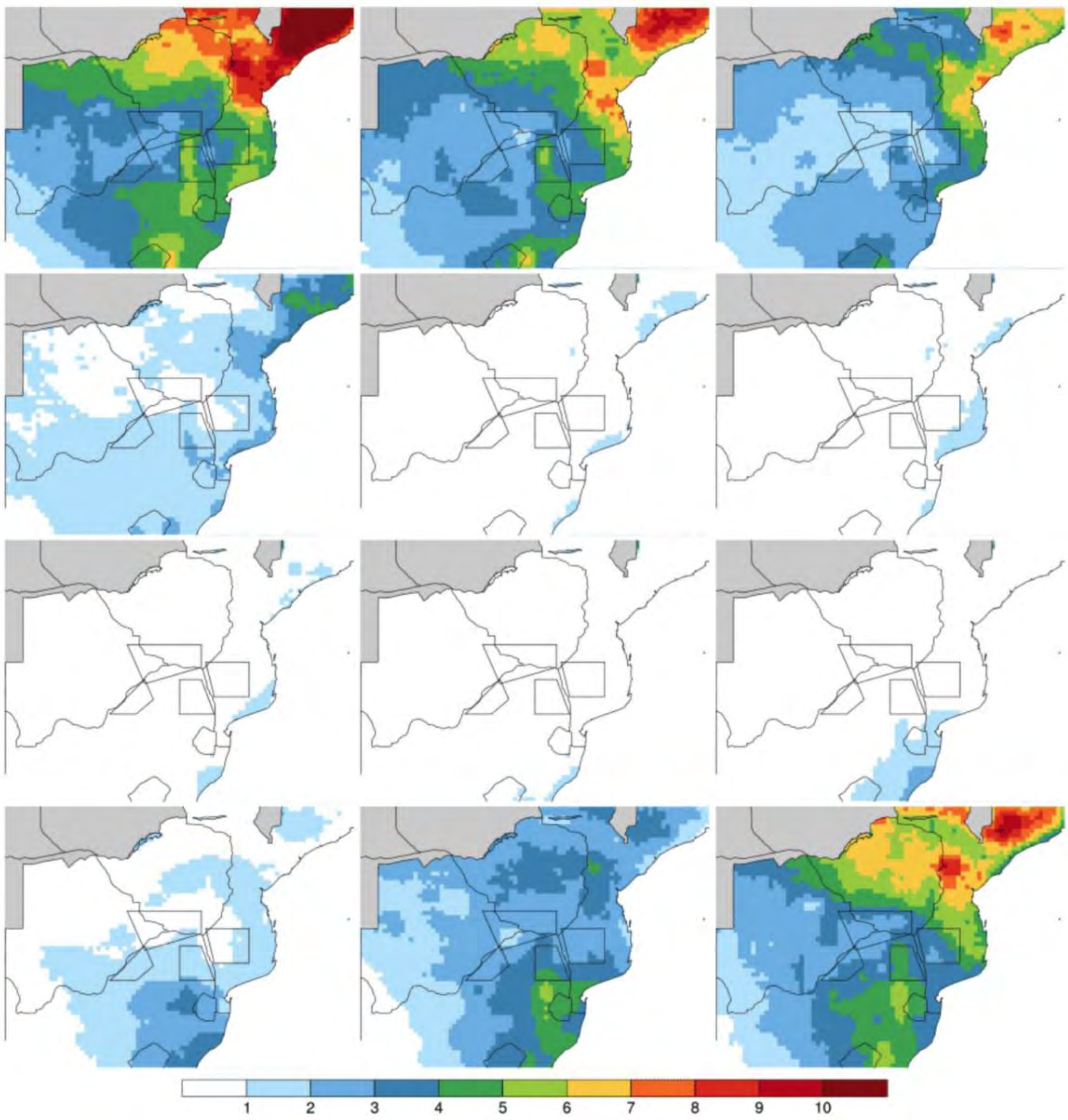
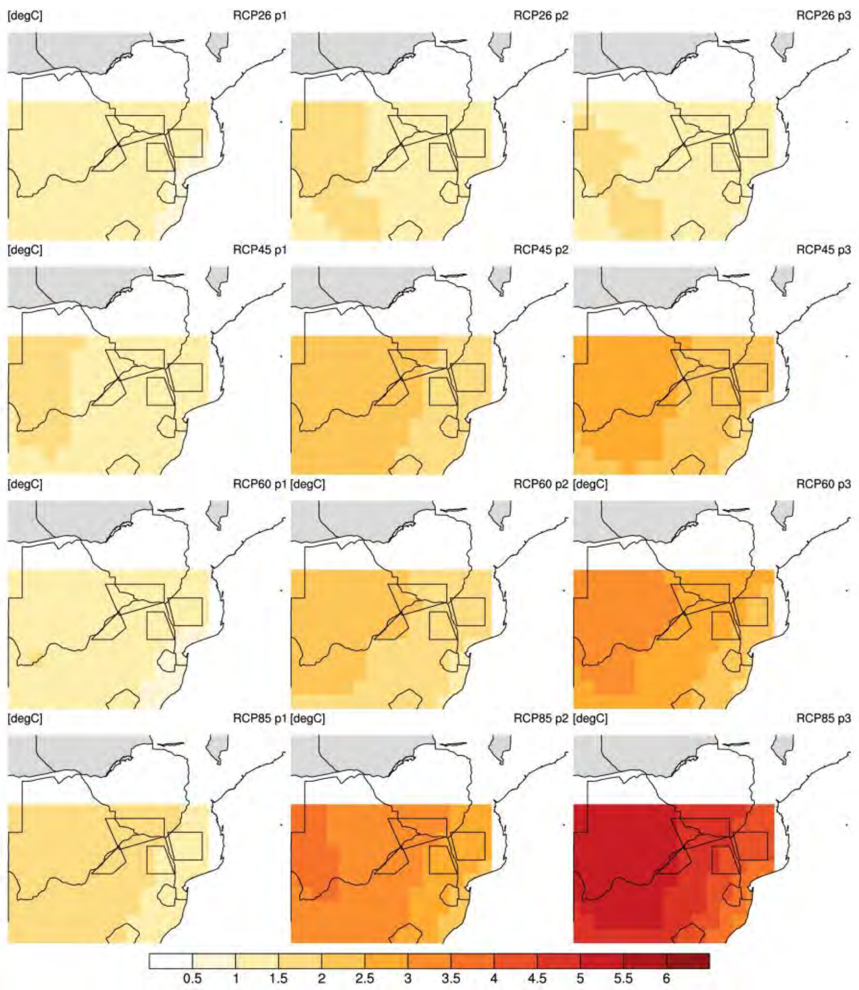


Figure 3. Monthly rainfall climatology according to TRMM; units are mm/day as per legend at bottom. Months read across then down, starting with January at top left. The four Domains over which the soms have been calculated are outlined

3 Some basic details of the CMIP5 projections

Temperature rises. Temperature rises according to the average across all CMIP5 projections, the ensemble mean (Fig. 4), are likely familiar from the IPCC AR5. Higher rises are to be expected with greater concentrations of atmospheric CO2, the highest under RCP8.5 reaching in excess of 5ºC by P3 (2075-2099)2, although these are mainly to the west of the Limpopo Basin. Increases are monotonic in time, i.e. there is a steady increase throughout, and are greatest in the central parts of the subcontinent furthest from the tempering effects from surrounding oceans. Were the Paris Agreement to be met, as represented best by RCP2.6, then the temperature rise would be less than 1.5ºC according to this analysis.

The distribution of standard deviations of the temperature calculated across all CMIP5 projections has a similar distribution in space and time to that of the ensemble mean of temperature itself (Fig. 5). It reaches about 1ºC over the central parts in P3, although a monotonic increase may not be apparent in time and CO_2 concentrations in all locations; this is likely a result of the relatively smaller number of projections available under RCP2.6 and RCP6.0 than under the other two RCPs rather than an indication of differential variability in this parameter.



2 If viewing the charts on a Mac then Digital Color Meter in the Utilities folder might assist in relating chart values at individual points to the captions on this and many future diagrams.

Figure 4. Average temperature increase from 1986-2005 across all CMIP5 projections according to the legend at the bottom. The top row is for RCP2.6, the second RCP4.5, the third RCP 6.0 and the bottom row RCP8.5. The left-hand column covers P1 (2025-2049), the central column P2 (2050-2074) and the right-hand column P3 (2075-2099). Blocks indicate the Domains over which the soms have been calculated..

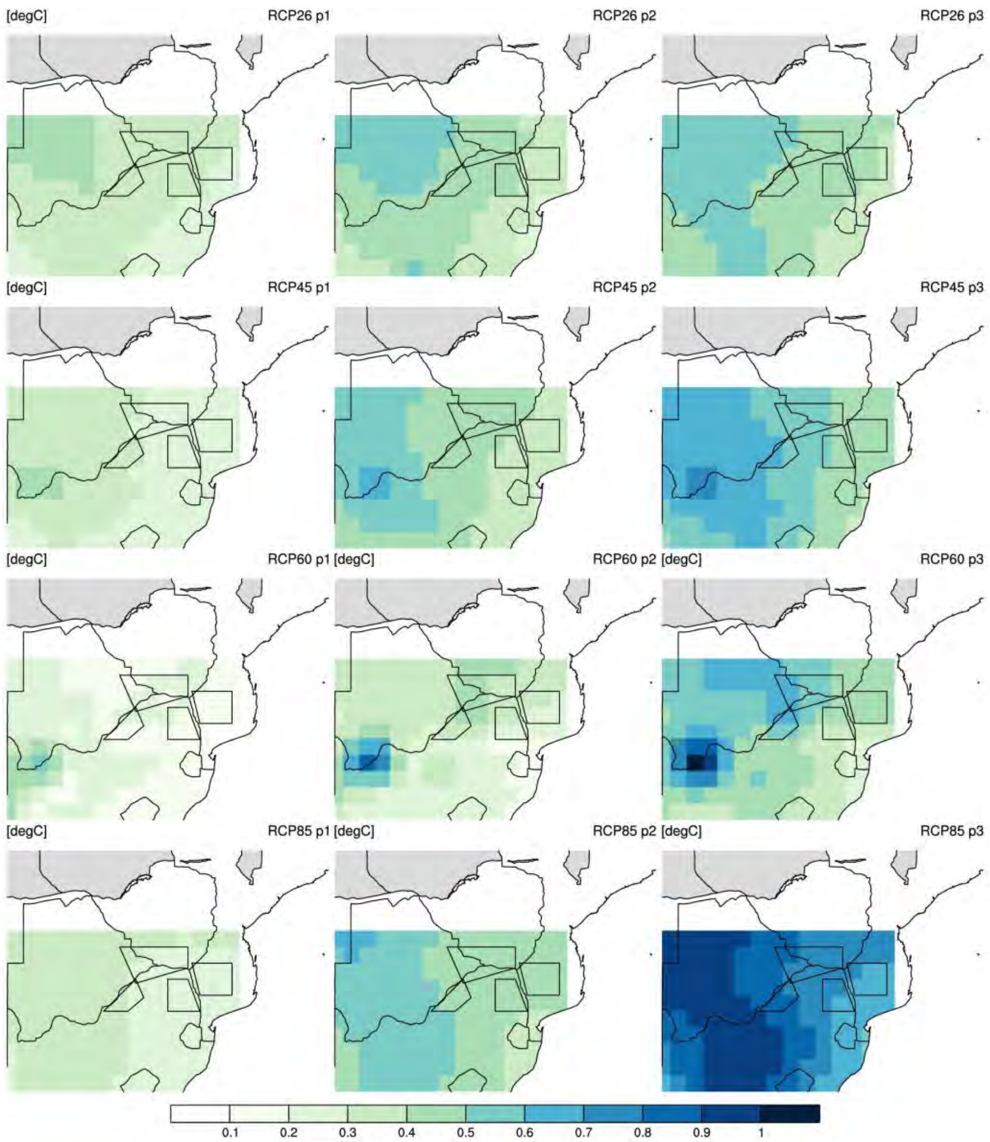


Figure 5. As Figure 4 but for the standard deviation of the temperature rises across the full CMIP5 projections

Changes in rainfall. According to the ensemble means, rainfall will decrease across the entire Limpopo Basin, perhaps most so towards the west (Fig. 6). The results have been calculated as ratios to the mean annual totals simulated by each model within the base period of 1979-2005. There is a general, but not absolute, pattern of greater rainfall decreases with higher RCPs; maximum values are in the west but are limited to under 20% under RCP8.5 over the Basin. Possibly the relatively fewer numbers of projections under RCP2.6 and RCP6.0 may help towards producing apparent non-monotonic trends in time. According to these results least harm is likely to be done if the Paris Agreement, as represented here by RCP2.6, were to be achieved.

The distribution of standard deviations of rainfall changes across all CMIP5 projections does not exhibit clear trends in terms of time or of RCP (Fig. 7). Lowest values, suggesting highest confidence (with caution) in the ensemble mean changes, are in the east, including much of the Limpopo Basin.

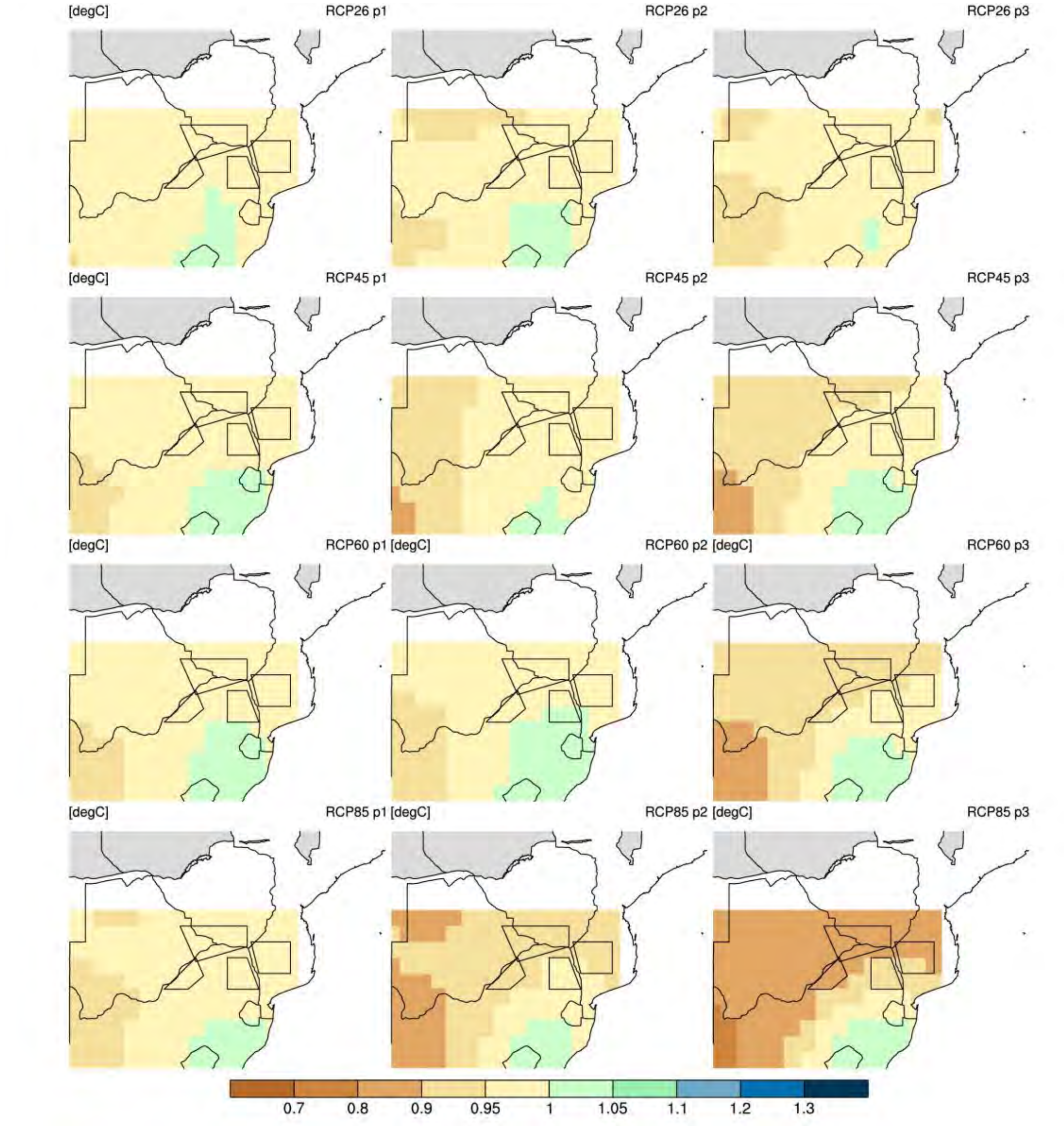


Figure 6. As Figure 4 but for changes in total annual rainfall as a ratio to that during the base period of 1986-2005.

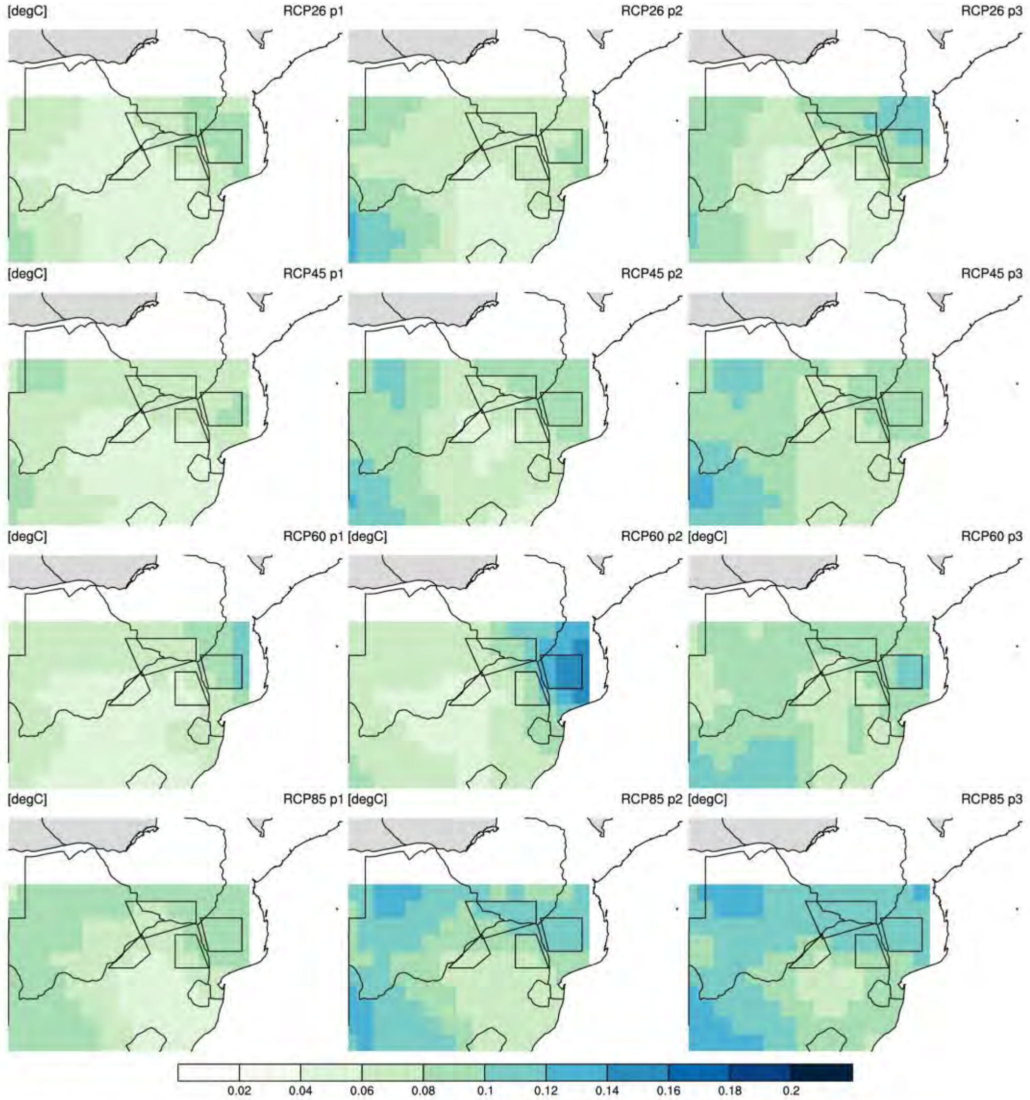


Figure 7. As Figure 4 but for standard deviations of rainfall.

Changes in rainfall less evaporation. Whereas the results above for temperature and rainfall may appear familiar from the IPCC AR5, the results following for rainfall less evaporation (RLE) do not appear in those volumes. Both rainfall and evaporation are simulated in the climate models and the differences have been calculated as a ratio to the values also simulated by each model for the base period 1979-2005. Evaporation, of course, responds to changing temperatures, and thus the precipitation less evaporation measure is more useful in hydrological applications than just rainfall alone in which increasing temperatures are not taken into consideration.

Average RLE ratios across the full CMIP5 projections suggest decreases, and therefore less basic water availability, across most central parts of southern Africa, but increases around much of the coasts (Fig. 8). The distributions are, perhaps, a little more noisy than those for temperature and rainfall changes, but this might be expected given the issues of simulating both rainfall and evaporation in the models. Worst affected regions might expect a reduction to below 70% of recent values according to this measure, in general to the west of the Limpopo Basin except, perhaps, for RCP6.0 and RCP8.5. Alternatively most simulations in Figure 8 suggest that RLE may increase over much of the Basin from the Zimbabwe-South Africa border eastwards. The water tower regions also may see little change in RLE according to Figure 8 despite the reduced rainfall over these areas according to the corresponding ensemble means (Fig. 6). Changes in either direction do not appear necessarily greater for the higher RCPs and thus achievement of the Paris

Agreement, as represented by RCP2.6, may have limited impact on rainfall less evaporation according to the ensemble means.

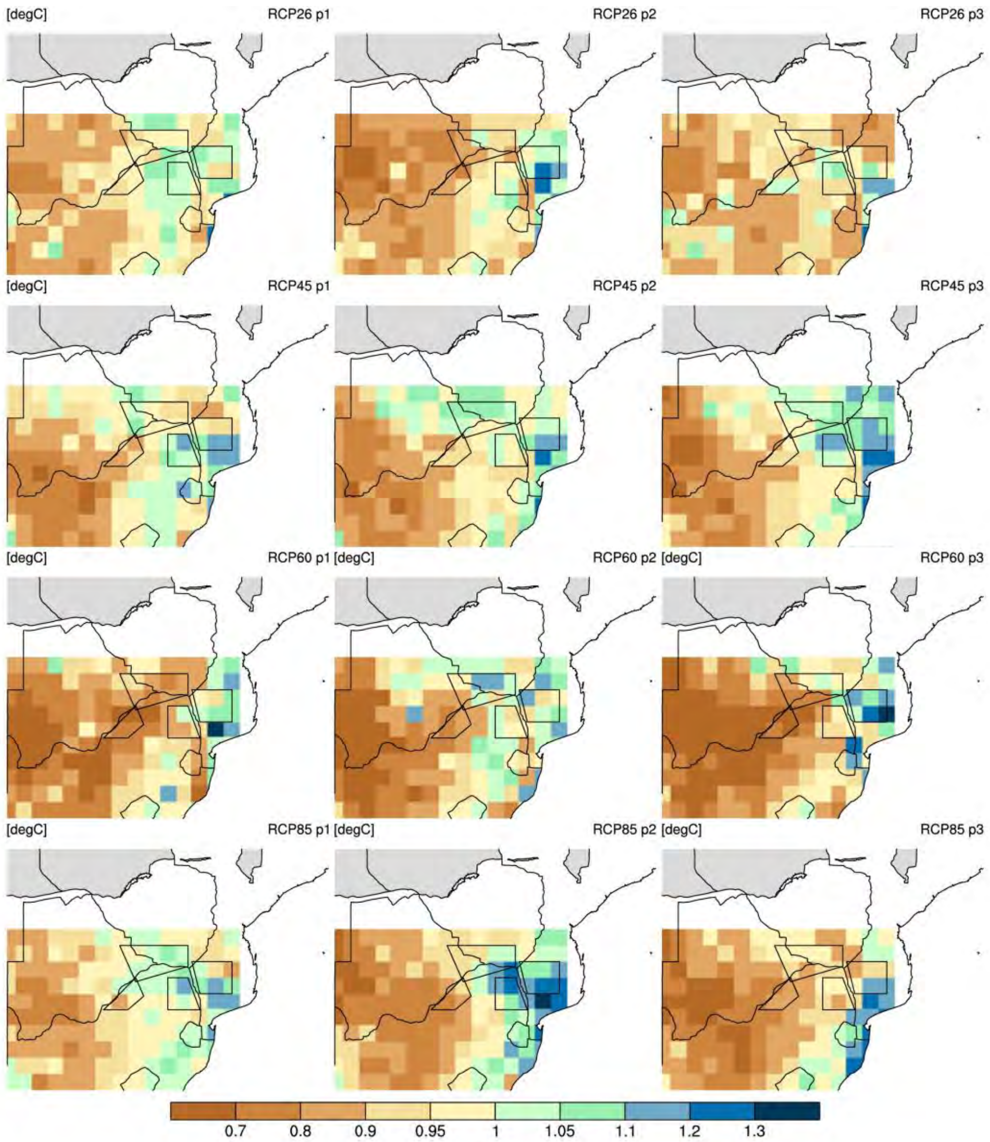


Figure 8. As Figure 4 but for the mean across the full CMIP5 projections for the difference between the rainfall and the simulated evaporation expressed as a ratio across the 1986-2005 mean values.

Standard deviations of RLE calculated across the full CMIP5 projections are certainly noisy, although values seem to be greater for those sets with the larger numbers of projections, i.e. RCP4.5 and RCP8.5 (Fig. 9). Nevertheless, there does seem to be a basic pattern of lower standard deviations across the regions with reduced RLE values in the ensemble mean, and higher values over areas with increased RLE values (apparently consistent with results for rainfall alone in Figure 6). However there also appears to be higher values over Mozambique. If correct, then this indicates that the models are more consistent amongst themselves in simulating future reduced RLE values over the central regions of southern Africa than they are in simulating increases around the coasts.

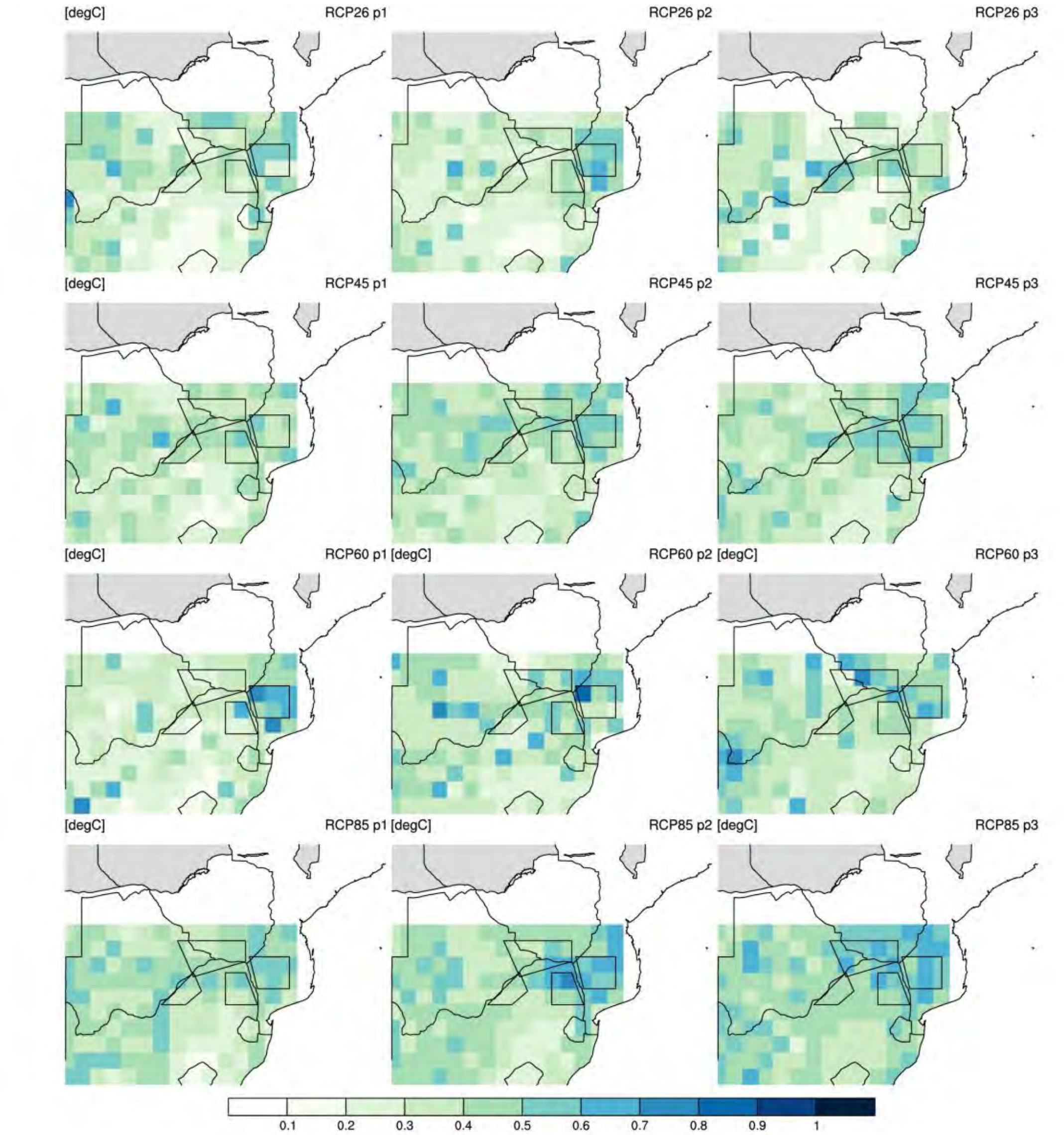


Figure 9. As Figure 4 but for standard deviations of the differences between the rainfall and evaporation.

Of possible interest is that the distribution of lowest future RLE ratios in Figure 8 appears to replicate the climatological rainfall distribution from the major rain-bearing systems over the central part of South Africa, the tropical-temperate troughs, or cloud bands (although no similar feature appears in the rainfall charts in Figure 6). Do these results suggest a change in water availability associated with these systems? It was noted earlier than there are suggestions that it is the distribution of rainfall from these cloud bands that may account, at least in part, for the relative aridity of the main Limpopo Basin in the vicinity of the Zimbabwe-South Africa border.

4 Scenarios from self-organising maps

For each Domain and for each RCP suggested scenarios have been created, as summarised in the separate documents for each Domain. From these suggested scenarios, recommended scenarios have been developed subjectively that attempt to capture the overall characteristics of the suggested scenarios for RCP2.6, RCP4.5 and RCP6.0. As has happened so often in previous soms analyses, scenarios for RCP8.5 stand a little apart from the remainder, not only in terms of higher temperature rises but often in terms also of larger precipitation departures. Thus RCP8.5 has been treated independently for all Domains.

The main conclusions from these separate analyses for each of the Domains are summarised in the following, drawn from the four documents. There are reasonably common conclusions for temperature changes in that these, by and large, increase with RCP and tend also to be higher for drier scenarios; hence the focuses in the following are on rainfall and rainfall less evaporation changes. The sequence is from the headwaters Domain, Waterberg, then downriver to the Zimbota and Mpumalanga and, finally, the Changane Domains:

Waterberg Domain: Rainfall changes in both directions appear in all suggested scenarios for individual RCPs, although the marginally higher likelihoods in general are for little change in all except RCP8.5, for which the outstanding likelihood is for a decrease. The picture is a little more complex for rainfall less evaporation. For both RCP2.6 and RCP4.5 there is an approximate 50-50 split in likelihoods for wetter (or at least little change) and drier conditions, although greater decreases than increases are projected; for both RCP6.0 and RCP8.5 the main signal is for a decrease in rainfall less evaporation, with substantial decreases possible at lower likelihoods.

Zimbota Domain: Rainfall changes in both directions appear in all suggested scenarios for individual RCPs, whether that might be an increase, or at least little change from current conditions, or a decrease, but with mixed signals in terms of likelihoods. The exception is RCP8.5, for which the likelihood of a decrease is notably higher than that of an increase. Overall the balance of likelihoods appears to be towards future decreases in water availability, or at best a limited increase if any. The picture is a little more complex for rainfall less evaporation. For RCP2.6, RCP4.5 and RCP8.5 there is a distinct bias towards future drier conditions, with an estimate of an 85% likelihood of drier conditions in RCP4.5. For RCP6.0 (note: with the lowest projections population) there is a slightly higher likelihood of future wetter conditions.

Mpumalanga Domain: Rainfall changes in both directions appear in all suggested scenarios for individual RCPs, although the marginally higher likelihoods in general are for little change in the two higher RCPs but for a decrease in the other two. The picture is a little more complex for rainfall less evaporation, with drier conditions having the higher likelihoods except for the lesser-populated RCP6.0. In all cases other than RCP6.0 some substantial increases in rainfall less evaporation are projected by some models, but in all cases these are with lower likelihood, i.e. they are projected by a small number of models that might be viewed as outliers to the main set of projections.

Changane Domain: Rainfall changes in both directions appear in all suggested scenarios for individual RCPs, although the higher likelihoods in general are for decreased rainfall in all RCPs. The picture is a little more complex for rainfall less evaporation, with drier conditions having the higher likelihoods throughout. In all cases some substantial increases in rainfall less evaporation are projected by some models, but in all cases these are with lower likelihood, i.e. they are projected by a small number of models that might be viewed as outliers to the main set of projections.

The main characteristics of these results for all Domains, based on RCP2.6, RCP4.5 and RCP6.0, are summarised in Table 1 following:

Table 1. Changes in rainfall and in rainfall less evaporation according to the recommended scenarios for each Domain for the three lesser RCPs separated according to a higher or a lower likelihood as assessed for each recommended scenario. ↑ - rainfall or rainfall less evaporation will increase; ↓ - rainfall or rainfall less evaporation will decrease; ◆ - following an arrow indicates likelihood estimated to be about 50%; • - after an arrow indicates little change.

	Rainfall		Rainfall less evaporation	
Domain	Higher	Lower	Higher	Lower
Waterberg	□□	□	□□	□
Zimbota	□□	□	□	□
Mpumalanga	□	□□	□	□
Changane	□	□	□	□

The results for rainfall as summarised in Table 1 indicate that in the north and west of the basin, covered by the Waterberg and Zimbota Domains, the higher likelihood is for an increase in rainfall, although the results suggest any increase to be minimal or perhaps largely a continuation of current conditions. In the east, for the Mpumalanga and Changane Domains, decreased rainfall is the more likely.

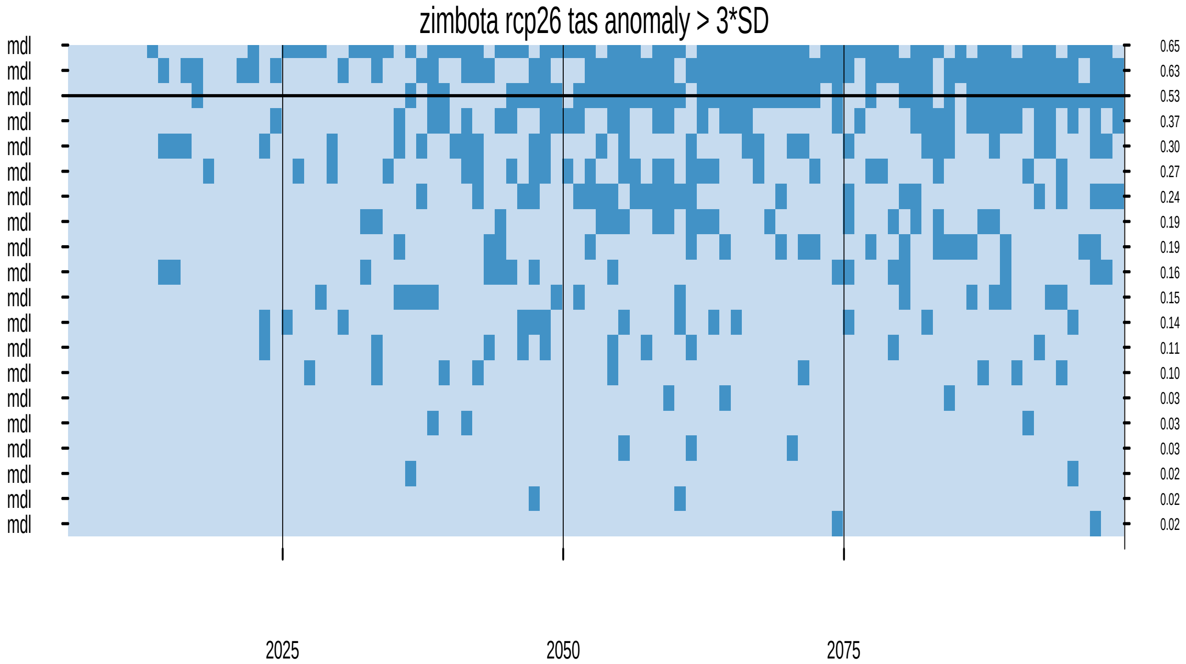
In terms of water availability as indicated by the rainfall less evaporation calculations it is only over the Waterberg Domain that any increase is the more likely, or though even here it might be marginal (see Table 1). Rainfall less evaporation is, of course, a better measure of water availability to the river system than rainfall alone, and thus overall these results suggest that water availability throughout most, if not all, of the Basin is most likely to decrease.

The results from the soms are replicated in the IAV calculations. Likelihoods of two- and three-year spells of temperatures exceeding two and three standard deviations as calculated from annual temperatures over the base period increase in time and by RCP and are similar for all four Domains. Were RCP8.5 to prove to be closest to actuality then two- and three-year periods of sustained heat above the two standard deviations are practically guaranteed by the 2060s, and above three standard deviations by the 2070s in all four Domains. Equivalent likelihoods are obtained only nearer the end of the century with RCP6.0 (which is noisy) and with RCP4.5. However, under RCP2.6 likelihoods peak towards the end of the century only at around 50-60% for two standard deviations and 30-40% for three standard deviations.

In previous reports values for the IPCC 'extreme' statistics, calculated from the CMIP5 projections, have been provided. The most useful temperature 'extremes' for the latitudes of the Orange-Senqu Basin are the Warm and Cold Spell Duration Indices, WSDI and CSDI, defined as the annual number of days in sequences of at least 6 days for which the daily maximum(/minimum) temperature exceeds the 90th percentile(/falls below the 10th percentile) of temperatures over the base period, 1961-1990, for that time of year. These are also measures of heat related to increased(/reduced) evaporation. Values of WSDI and CSDI are not presented here: the consistent picture is one of increasing numbers of days in sequences of warm spells, and of decreasing numbers of days in sequences of cold spells, with departures increasing both later in the century and under higher RCPs.

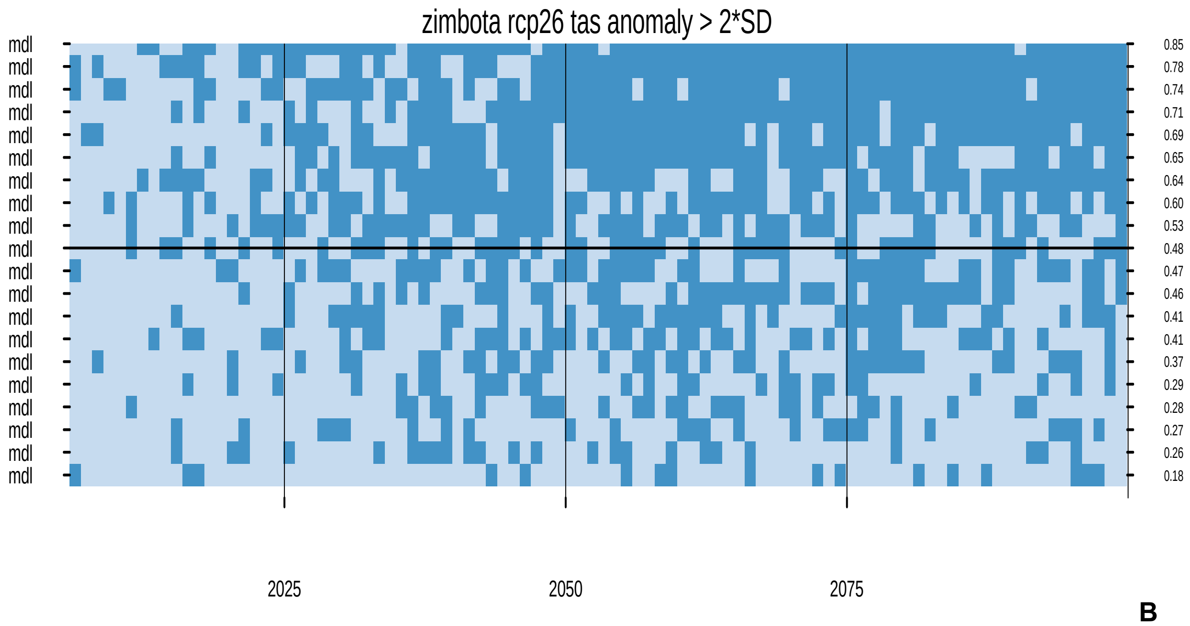
In order to offer a clearer idea of the meaning of the temperature IAV calculations the charts below in Figure 10 illustrate the individual years in which annual temperatures exceed two and three standard deviations for each projection for the Zimbota Domain under RCP2.6 and RCP8.5 separately:

A



zimbota rcp26 tas anomaly > 3*SD
mdl
0.65
0.63
0.53
0.37
0.30
0.27
0.24
0.19
0.19
0.16
0.15
0.14
0.11
0.10
0.03
0.03
0.03
0.02
0.02
0.02
2025
2050
2075

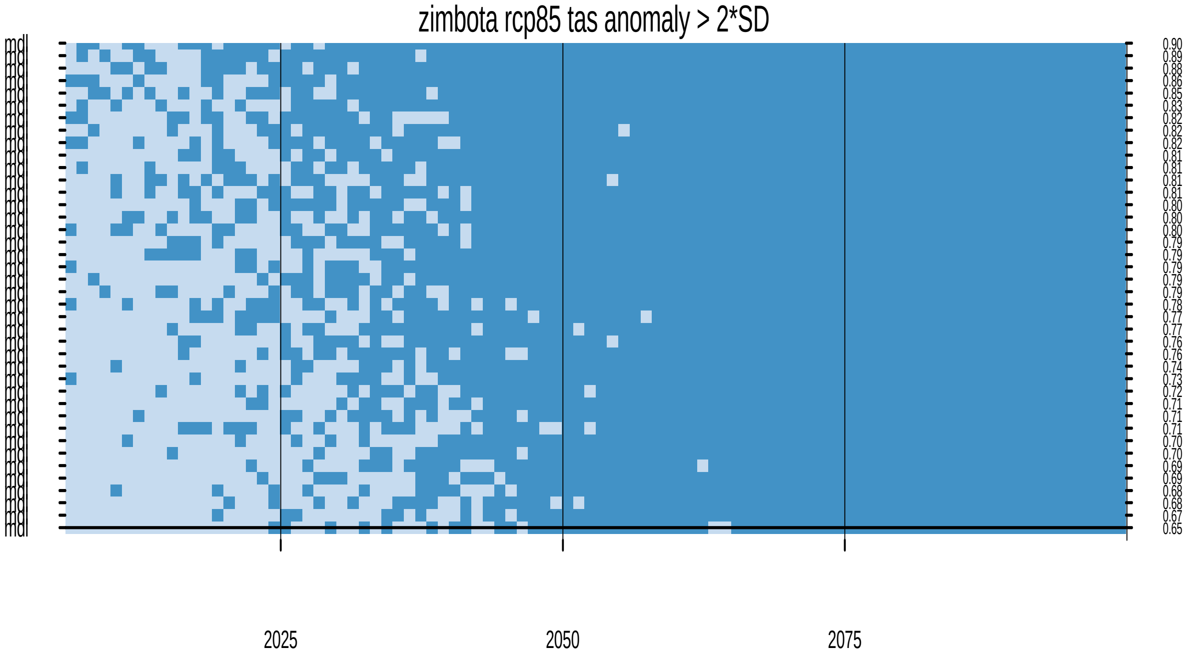
B



zimbota rcp26 tas anomaly > 2*SD
mdl
0.85
0.78
0.74
0.71
0.69
0.65
0.64
0.60
0.53
0.48
0.47
0.46
0.41
0.41
0.37
0.29
0.28
0.27
0.26
0.18
2025
2050
2075

B

C



D

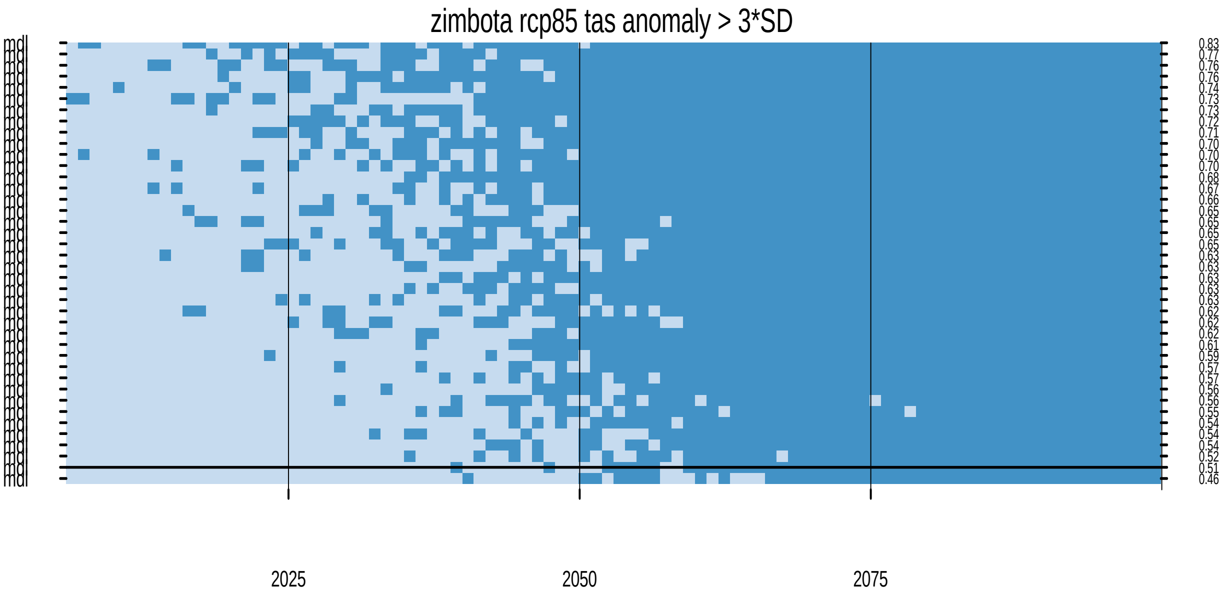
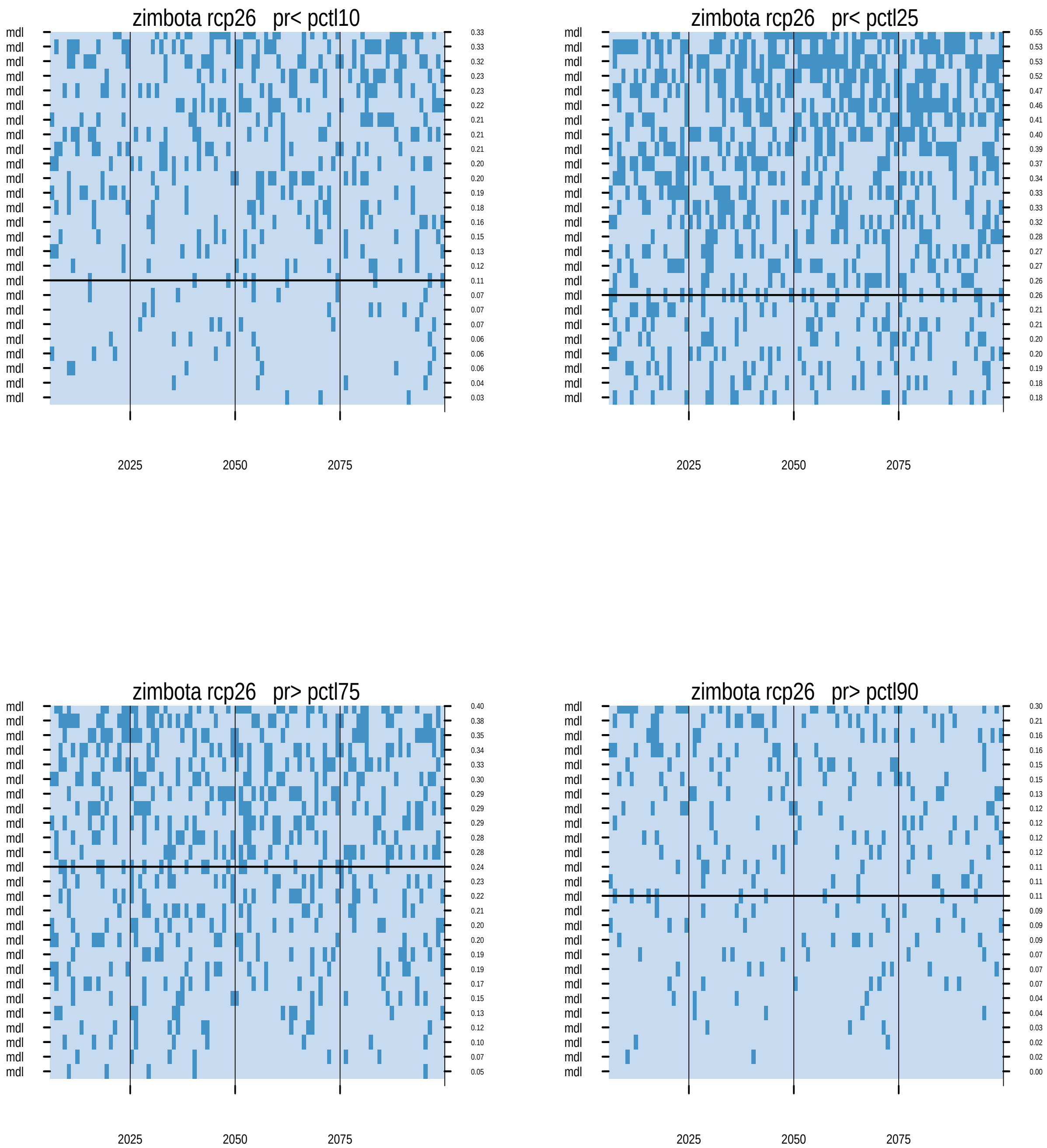


Figure 10. Distributions of projections in time for all individual models within CMIP5 for the Zimbota Domain for which the mean annual temperature as compared to that for those during the base period of 1986-2005 exceeds: A 2 standard deviations under RCP2.6; B 3 standard deviations under RCP2.6; C 2 standard deviations under RCP8.5; D 3 standard deviations under RCP8.5. Each line represents a projection from an individual model with all CMIP5 projections represented. The vertical axis is arranged with the projection giving the greatest frequencies of events over the entire period at the top down to that with the lowest frequencies at the bottom.

Note that the presentation in Figure 10, for which the years in excess of two or three standard deviations have been identified individually, differs from that in the IAV statistics, for which sequences of two and three years above the two standard deviations levels have been employed. From A and B in Figure 10, for RCP2.6, it is clear that some models develop future annual temperatures above the thresholds relatively quickly and persistently whereas others produce few during the century. A similar observation may be applied to C and D in Figure 10, for RCP8.5, although in this case all models ultimately project temperatures in all years to exceed the thresholds. Without going into further details the fundamental reason for the differential projections revealed in Figure 10 is the disparate extents to which the formulations of the various models respond to increasing concentrations of atmospheric CO_2.

Equivalent results for rainfall and for RLE over the Zimbota Domain under RCP2.6 and RCP8.5 are shown in Figures 11 and 12.

A



B

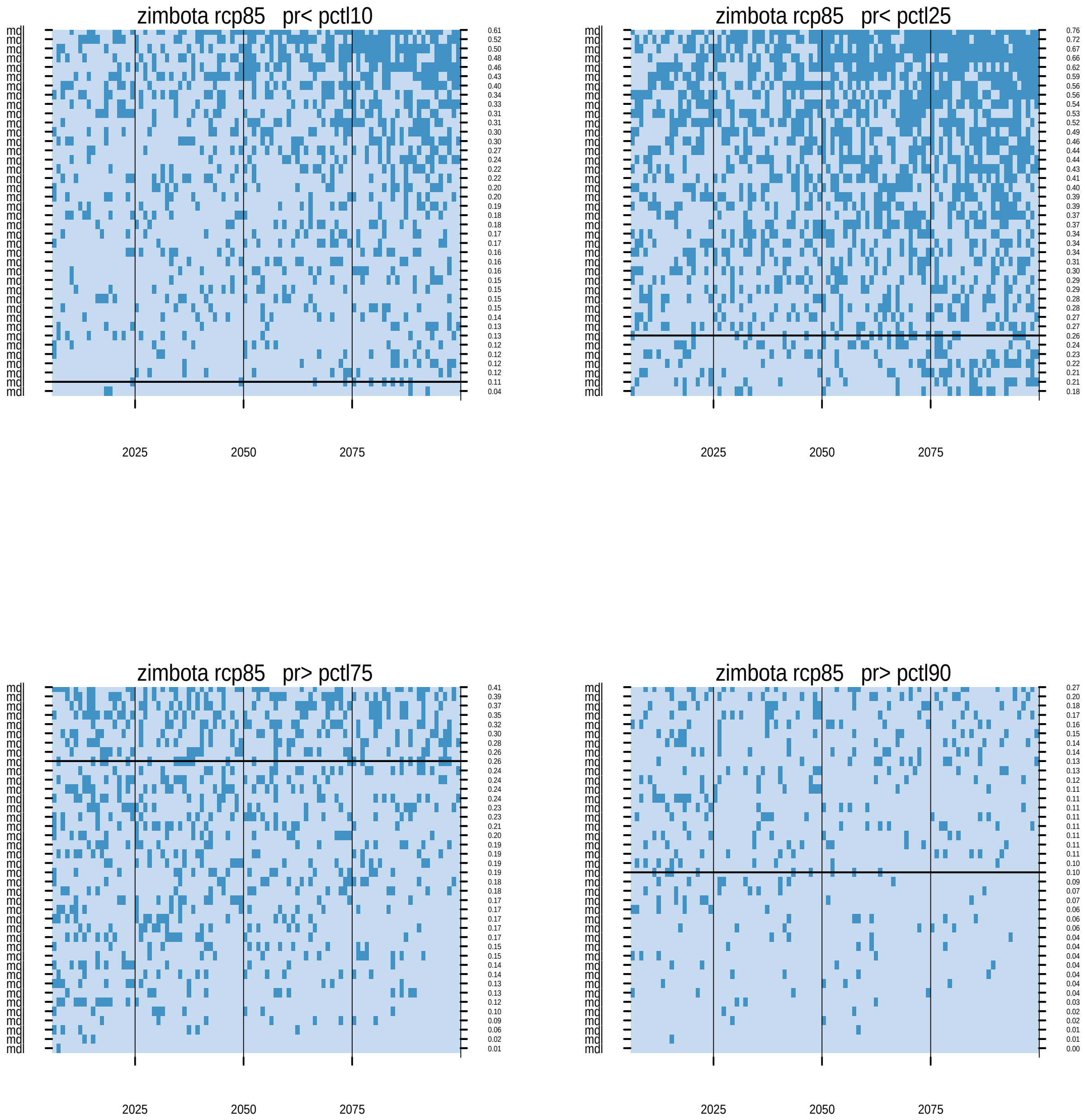
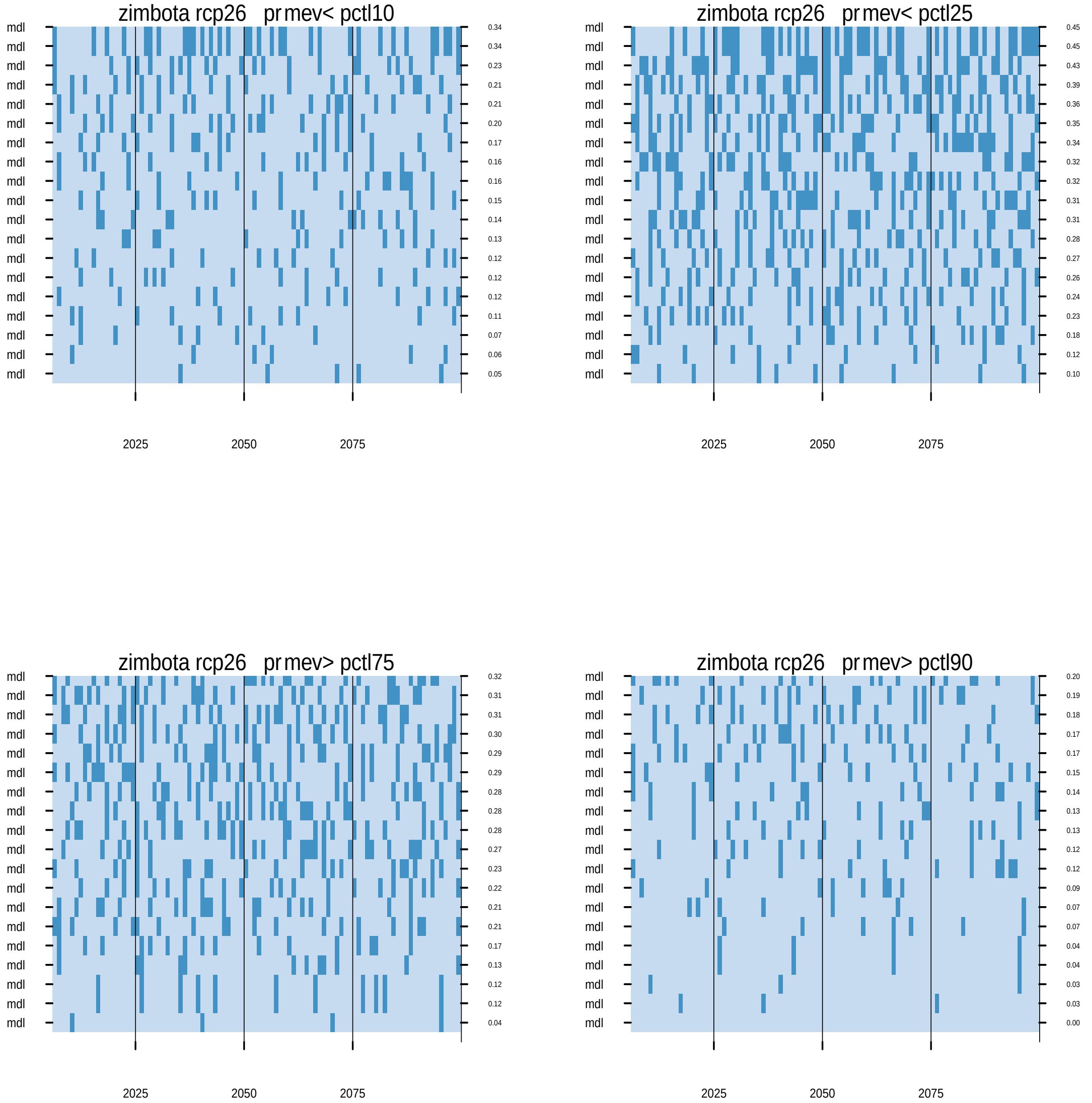


Figure 11. Similar to Figure 9 but for rainfall over the Zimbota Domain. A: under RCP2.6. B: under RCP8.5. In both A and B the top left hand chart indicates occasions when each model (each row covers a projection for each model separately) simulates annual (*not* two-or three-year totals) below the 10th percentile calibrated across the base period of 1986-2005; similarly the top right hand chart occasions below the 25th percentile; similarly the bottom two charts occasions above the 75th and 90th percentiles as indicated. Indicators on the y axis of all right-hand side charts may be ignored.

A


zimbota rcp26 pr mev< pctl10
zimbota rcp26 pr mev< pctl25
zimbota rcp26 pr mev> pctl75
zimbota rcp26 pr mev> pctl90
mdl
2025
2050
2075

B

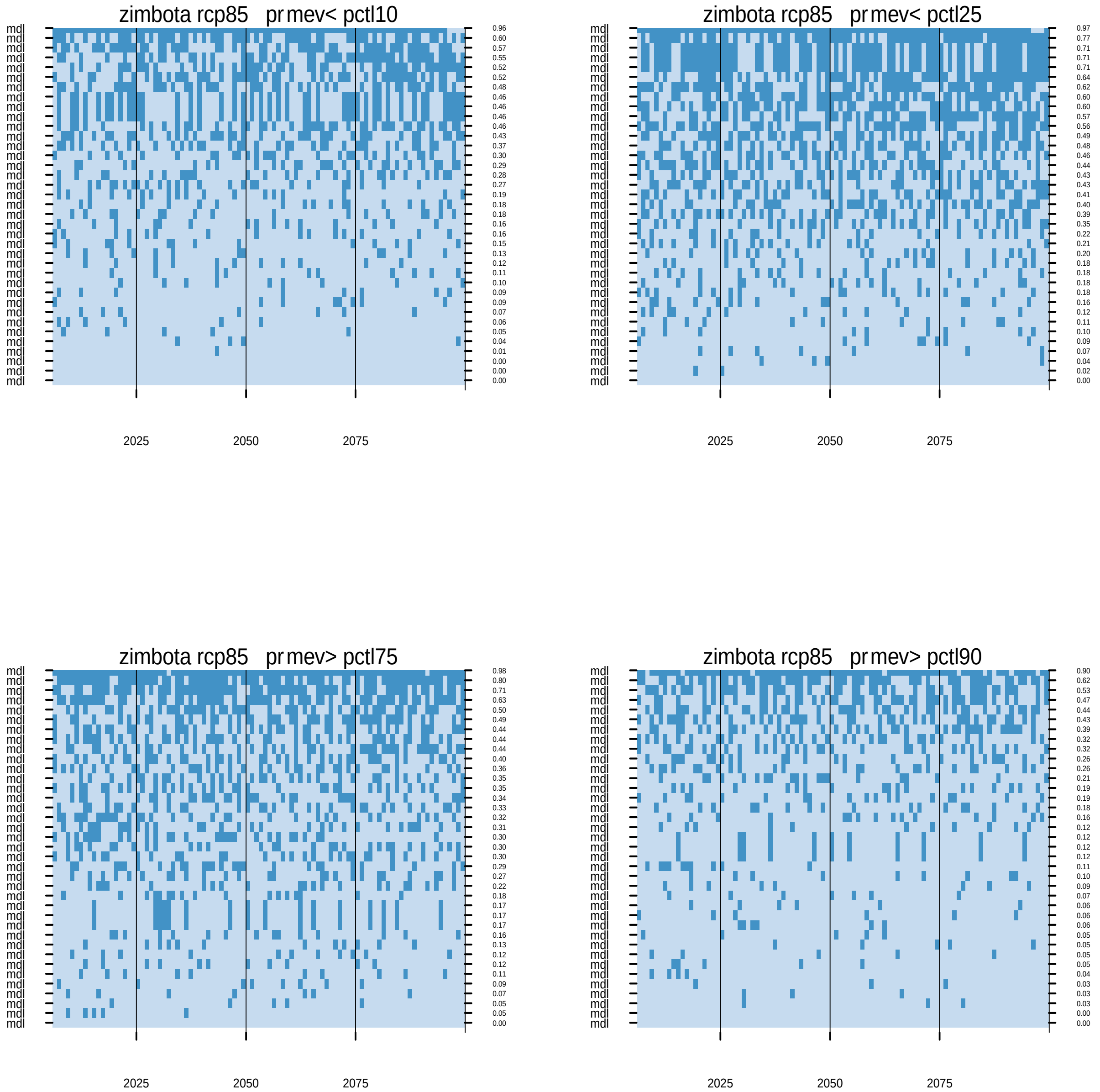


Figure 12. As Figure 11 but for rainfall less evaporation.

Probably the immediate observations from Figures 11 and 12 are the intermittencies of the low and high rainfall/RLE events and the disparate simulations of these by the various models, with some models simulating relatively frequent events and others only rarely so if at all.

Equivalent diagrams to Figures 10, 11 and 12 are available on request for all Domains and all RCPs.

For all four Domains the IAV results for all projections for each RCP (shown as the second diagram in each of the separate Domain documents, i.e. Figures WB, ZB, MB and CB), which present a clearer picture than the equivalents for the individual soms, are consistent in suggesting that the frequencies of events below the 10th and 25th percentiles will increase through the century, something that is present for all RCPs but is most prominent for RCP8.5. For events above the 75th and 90th percentiles there may be decreasing trends in frequencies through the century, again perhaps most prominently for RCP8.5, but these trends appear not to be as strong as those for the 10th and 25th percentiles. Together these results indicate a skewing of annual rainfall totals towards more frequent drier years even if, as suggested in Table 1 above for the Waterberg and Zimbota Domains, there is little change in annual totals themselves.

The equivalent results for the RLE calculations (see Figures WC, ZC, MC and CC) perhaps suggest an upward trend in events below the 25th percentile, maybe also for those below the 10th percentile, an in again in particular for RCP8.5, but those trends may not be present for all RCPs. Similarly, there are no immediately apparent trends for events above the 75th and 90th percentiles. Thus, in the larger picture, although this will not be consistent for all soms, there may be limited overall change in terms of water availability as measured by RLE regardless of any changes in rainfall. A more detailed analysis would be required to determine the dependencies of the above conclusions in regard to the recommended scenarios.

5 Conclusions

Climate change projections for the Limpopo Basin have been made separately by the CSIR and reported in two documents:

1. E. Kapangaziwiri, J-M. W. Kahinda, N. Oosthuizen, V. Mvandaba, P. Hobbs and D. Hughes; 2017: Upstream-downstream hydrological linkages in the Limpopo River Basin
2. Prepared by GIZ for LIMCOM; 2013: Limpopo River Basin Monograph

Both are based on an ensemble average of six models, but details of the approach are given only in the first of the above reports and details of results in a form comparable with those in this report only in the second. In the following it is assumed that the approach taken in the first is consistent with the results in the second.

There are some differences in the approach taken to that used here, notwithstanding the numbers of models and analysis techniques employed:

- The base period is 1961-1990 as compared to 1979-2005 used in the current report; the later base period may be warmer than the earlier one, thus reducing projected temperature changes by a fraction of a degree, but equivalent effects on rainfall and RLE are unknown; note that the base period used in the sequence of IPCC reports has become later in each volume, reaching 1986-2005 in the AR5
- The projected periods are 2011-2040 and 2071-2100, as contrasted with 2025-2049, 2050-2074 and 2075-2099 in the current report
- Emissions scenarios used are A1B from the SRES series and RCP4.5, as contrasted with RCP2.6, RCP4.5, RCP6.0 and RCP8.5 in the current report; see Appendix 3 for more details of the SRES and RCP emissions scenarios but A1B is perhaps closer to RCP6.0 than to RCP4.5; therefore these scenarios do not scan as wide a distribution in future emissions as the full set of four RCPs
- Model versions tend to change between IPCC reports and therefore may differ between those using SRES A1B and those using RCP4.5 in the CSIR work; likely the models using RCP4.5 in the CSIR report are the same versions as those used in the current report.

The overall effect of these differences is unknown, and it possible the 2017 report used newer model versions and different emissions scenarios than that in 2013.

Given the caveats above then according to the second report temperatures over the Basin will increase by 1-2ºC during 2011-2040. This range is reasonably consistent with the changes in the recommended scenarios derived in this report for the 2025-2049 period for scenarios based on both RCP2.6 plus RCP4.5 plus RCP6.0 and on RCP8.5.

CSIR results for rainfall are illustrated in Figure 13:

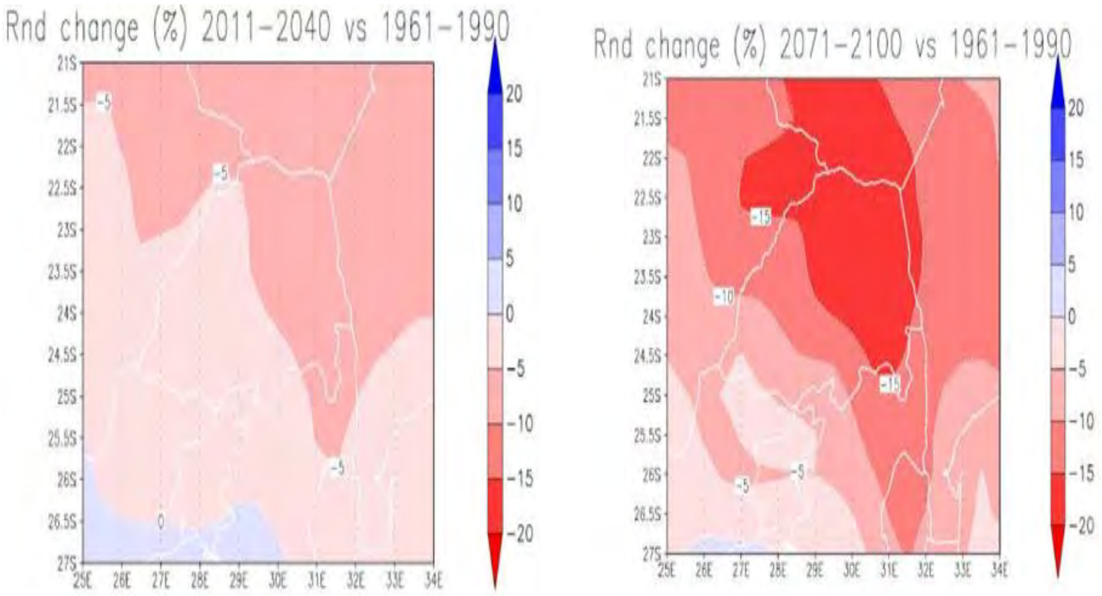


Figure 13. Projected rainfall changes over the Limpopo Basin as derived by the CSIR (see text for details); legends to the right of each diagram.

Rainfall will decrease over all parts of the Basin according to Figure 13, with the decrease exceeding 15% in the later period, and indeed perhaps 20% in places according to the accompanying text. Recommended scenarios for rainfall for all four Domains in the current report include some that are roughly consistent with these CSIR values, with some suggesting even greater reductions. Alongside this observation, however, must be placed the fact that the recommended scenarios with decreased rainfall are not always those with the highest likelihoods and that maintenance of current levels or even increased rainfall are envisaged in other recommended scenarios.

It is not possible to make any similar comparisons to the above for the rainfall less evaporation projections.

Perhaps the critical considerations revealed in the current report, and perhaps not realised to a similar degree in Report 2, are:

- The complexities of projected climate change across different sections of the Basin
- The sensitivities of the results to emissions scenarios, with distinct indications that impacts are least under RCP2.6, i.e. were the Paris Agreement to be achieved
- There can be substantial differences in the details of future rainfall (and rainfall less evaporation – RLE) distributions, in particular, between individual models, pointing to the care that needs to be taken were a subset of projections to be selected.

Temperature rises according to the recommended scenarios are similar for all Domains, although with a suggestion of perhaps greater increases over the Waterberg and Zimbota Domains, those two closest to the largest increases in the CMIP5 ensemble mean (Fig. 4). Future distributions of temperature rises from the IAV (inter-annual variability) assessments are also similar, with all Domains likely to suffer extended periods of temperatures above two and three standard deviations in the latter parts of the Century under all scenarios except those for RCP2.6; these will not be discussed further below.

The recommended scenarios based on rainfall using RCP2.6, RCP4.5 and RCP6.0 are as follows:

- **Waterberg Domain**

%	2040	2065	2080
55	1.00ºC/1.00	1.75ºC/1.00	2.00ºC/1.00
45	1.00ºC/0.95	2.00ºC/0.95	2.75ºC/0.90

- **Zimbota Domain**

%	2040	2065	2080
60	1.25ºC/1.00	1.75ºC/1.05	2.00ºC/1.00
40	1.50ºC/0.95	2.00ºC/0.90	2.75ºC/0.85

- **Mpumalanga Domain**

%	2040	2065	2080
60	1.25ºC/0.95	1.50ºC/0.95	2.00ºC/0.90
40	1.00ºC/1.05	1.50ºC/1.05	2.25ºC/1.00

- **Changane Domain**

%	2040	2065	2080
60	1.25ºC/0.95	1.50ºC/0.90	2.00ºC/0.90
40	1.00ºC/1.10	1.50ºC/1.05	2.00ºC/1.10

Apart from adjustments in likelihoods there is little to choose between the rainfall scenarios, with perhaps a greater risk of higher decreases in the Zimbota Domain, and equally of larger increases in the Changane Domain. The capabilities of the CMIP5 models to simulate tropical cyclones, and changes in these, is limited, and thus this may be a factor not adequately simulated in the Changane Domain, although rare storms also penetrate to the Zimbota Domain.

Similarly, for the rainfall less evaporation recommended scenarios:

- **Waterberg Domain**

%	2040	2065	2080
60	1.25ºC/1.00	1.75ºC/1.05	2.00ºC/1.05
40	1.50ºC/0.80	2.00ºC/0.70	2.50ºC/0.60

- **Zimbota Domain**

%	2040	2065	2080
65	1.50ºC/0.75	2.00ºC/0.80	2.50ºC/0.80
35	1.25ºC/1.05	1.50ºC/1.25	1.50ºC/1.30

- **Mpumalanga Domain**

%	2040	2065	2080
55	1.25ºC/0.90	1.50ºC/0.75	2.00ºC/0.85
45	0.75ºC/1.10	1.50ºC/1.10	2.00ºC/1.25

- **Changane Domain**

%	2040	2065	2080
70	1.25ºC/0.80	1.75ºC/0.80	2.00ºC/0.85
30	1.00ºC/1.50	1.50ºC/1.50	1.75ºC/1.75

Highest projected values of RLE reductions are in the Waterberg Domain, albeit at lower likelihood. Other reductions in the appropriate scenarios are all of order 20%. Increased RLE projected values are lowest also for the Waterberg Domain, with highest, at relatively low likelihood, over the Changane Basin (perhaps a reflection of tropical cyclone activity?). Nevertheless, based on the RLE scenarios most of the Limpopo Basin is more likely (but not certain) to be subjected to reduced water availability.

Naturally potential departures of both rainfall and of RLE might be larger should RCP8.5 prove to be the closest emissions scenario to reality. The suggested extremes scenarios indicate the approximate maximum changes in either direction possible according to the CMIP5 ensemble; naturally these departures are greater than those discussed above.

6 Appendices

Appendix 1. A review of issues for climate projections of limited areas

The only viable approach available for assessing climate change is through the use of mathematical models, run on powerful computers, which simulate the climate over future decades. This is the approach used by many research organisations with results summarised by the IPCC in its various Assessment Reports (AR). The latest, the AR5, was produced in 2013/14.

Climate models have been developed continuously over recent years and progress has been reflected in each succeeding IPCC AR. The most advanced models (c. 20) used as the basis of AR4[3] in 2007 simulated both the atmosphere and the oceans in some detail. Although such models have progressed further for the AR5, and still provide the major information used (from over 30 models), they have been joined by more complex models that either incorporate additional details of the total environmental system, or cover reduced regions at higher spatial and temporal scales than the global models (Regional Climate Models – RCMs), or have systems of creating numerous projections from a single model by making realistic changes directly to various settings in the model, one approach to making an ensemble[4].

In order to run climate models, information is needed on future atmospheric GHG concentrations, which is provided through an emissions scenario approach (see fuller details in Appendix 1). In the AR4, the emissions scenarios used included: A2, a scenario with relatively high future emissions through rapid economic development based on carbon-based energy generation; and B1, in which globally-cooperative decision making prioritising the environment helps reduce emissions. For the AR5 a different approach was used, referred to as Representative Concentration Pathways, RCPs, with emissions and atmospheric GHG concentrations increasing successively through RCP2.6, RCP4.5, and RCP6.0 to RCP8.5. Roughly speaking, A2 is equivalent to RCP8.5 and RCP6.0 is about halfway between A1B (a relatively high emissions scenario) and B1 (similar to RCP4.5). RCP2.6 ultimately leads to zero net emissions after about 2070 and is the only scenario that, if broadly followed, would offer a reasonable chance of reaching the UNFCCC target of restricting the average global temperature rise to below 2°C. Observed emissions to date have tended to follow approximately those of scenario A2 and RCP8.5.

Any differences in projections provided by the various climate models using a particular emissions scenario can be traced predominantly to the way in which each model has been formulated. As noted above, climate models are mathematical representations of the climate system. All climate models handle the mathematics through somewhat different approaches, and not all models simulate all processes in the climate system. In addition, certain calculations within the models require the use of estimated values, and the projections produced by any model may change with even minor but reasonable changes to these values. It is changes to these estimated values that have been used to produce an ensemble with a single model, as mentioned above.

In summary, the outcome of the issues précised above is that no two models, or versions of a single model, will produce identical projections. Relatively small changes to the structure of a model may have a disproportionately large impact on the projections produced. Predictability theory in fact requires such differences in projections to occur: if two independent models produced identical projections then there would be concern over the validity of these projections. Thus, with numerous climate models, or their variants, being used to produce an ensemble of individual projections, none the same, there is an issue of how to interpret the broad spread of information produced. Several approaches have been used:

- At the simplest level is the identification of a preferred single model based on some approach. Unfortunately, there is no evidence to guide appropriate selection and predictability theory is clear in

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3 Note that, technically, the dataset used in the AR4 is known as CMIP3 and that used in the AR5 as CMIP5.

4 An ensemble is a set of model predictions/projections, all for the same future period, produced either by variations of a single model, or by a group of different models, or by a combination of both methods.

indicating the limitations of this approach. Published papers frequently use this approach. It is quite valid as an examination of the performance of a particular model but caveats are needed if this approach is used to prepare scenarios for planning purposes. It is certainly not recommended as a basis for adaptation planning, although it has been used.

- At the next level is the identification of a small number of preferred models from the complete ensemble. However, there is no more justification in predictability theory for selecting a subset of models than there is for selecting a single model. Nevertheless, this approach has been used frequently in adaptation planning and in National Communications to the UNFCCC (as has the single model approach).
- The only approach that begins to satisfy predictability theory is to create and interpret as large an ensemble as possible. There are various ways of doing so. The main one used by the IPCC is to use all available models from the various climate modelling centres (although, as noted above, advances have been included within the IPCC AR5 that also produce large ensembles from a single base model by varying some of the estimated values). Most, if not all, National Communications do not use ensembles of anywhere near the size available to the IPCC.

With the full AR4 and AR5 ensembles running to 20 or 30 or more projections respectively, various interpretive approaches have been used both by the IPCC and elsewhere:

- The simplest approach, and most popular technique, is to take mean values (sometimes median values) across all individual projections within the ensemble, as it permits a straightforward deterministic interpretation to be provided. It is used commonly throughout IPCC reports. According to predictability theory taking an ensemble mean is an appropriate technique to use, as it averages out those aspects that are 'unpredictable' leaving behind a summary of the 'predictable' elements. However, two caveats underlie this theory. The first is that values across all projections within the ensemble have a normal distribution. Experience indicates that often this is not so, particularly for rainfall. The second caveat is that the ensemble is formed 'properly'. In effect, this means that the ensemble is assumed to provide a complete distribution of all realistically possible future states with each given its correct probability of occurring. No tests have ever been made on the IPCC projections of this second caveat, for entirely pragmatic reasons, but experience with ensembles at shorter timescales indicate that the IPCC ensembles are unlikely to be proper. Considerable research was required before this caveat could be addressed at the shorter time scales. Use of the ensemble mean as the sole basis for planning, therefore, however straightforward, is not recommended. Whenever it is used appropriate measures of uncertainty should be added. Despite these issues, some results using this approach, with caveats as noted, are provided below.
- The next approach is to provide a range of possibilities based on the ensemble, with the range typically expressed around the ensemble mean. This approach is also used by the IPCC and certainly provides a limited degree of advice about the uncertainties involved as suggested by an ensemble. Nevertheless, the two caveats mentioned above remain an issue. In fact the caveats need to be broadened. Predictability theory indicates that a properly formed ensemble cannot and should not encompass the entire probability distribution of future states. Hence, for a properly formed ensemble, there is always a possibility of the "answer" lying completely outside the range of the ensemble, that possibility decreasing as the ensemble size increases. Any range that lies fully within the ensemble is ignoring possible future states, even though sometimes these ranges are calculated in terms of a 95% or 99% coverage based on the ensemble itself. How large is large enough for an ensemble? If properly formed then the probability of the "answer" lying outside the complete ensemble range is roughly 10% for an ensemble of size 20 (about the AR4 size) and about 5% for an ensemble of 40 (slightly larger than the AR5 size). However, adding members eventually becomes a matter of decreasing returns in some regards, although the point at which this applies with climate projections is unknown at present. With current technology it is probably best to assume that the larger the ensemble size the better. Nevertheless, inherent biases still remain in the IPCC ensembles, as not all models included are independent, i.e. different versions of the same base models are sometimes included.
- The only approach that provides all information inherent within an ensemble is to calculate probability distributions for each variable at each point and time of interest (with the assumption that the ensemble is properly formed). While the IPCC provides some information along these lines, it focuses principally on the average/range approaches outlined above. Probability distributions are often not popular amongst users who may find them difficult to interpret. In addition not all published

probability distributions consider the fact that the “answer” may lie outside the ensemble; none are able to consider that the ensemble may not be proper. One major disadvantage of this approach is that the vast amount of information produced can readily overwhelm the user.

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Appendix 2. An introduction to the interpretation of self-organising models applied to climate change projections

Self-organising maps (soms) is a statistical technique that collates similar values within the full set of possibilities as laid out in a data set such as the one created by the various parameters in the AR5 projections. It is a type of neural network but in the manner in which it is used here it might be easier to think of it as a clustering technique. A typical clustering approach is designed to identify a group of similar values within a data set and to separate these from other equivalent groupings within the data set, which is exactly the objective here insomuch as it is to identify one or more projected future pathways of the climate each supported by the larger numbers of projections.

Clustering analysis has been in frequent use in recent decades to explore distributions of values within large data sets, and soms has now become a similarly popular approach. One reason that soms analyses may be used in preference to clustering is that most clustering techniques assume a fundamental underlying statistical distribution of the data within a set, normally Gaussian. That assumption immediately constrains the manner in which the groupings are identified in way that might be inappropriate for the data set. Certainly, examination of regional rainfall distributions across the CMIP5 projections indicates that these are not necessarily Gaussian. With soms no assumptions are made regarding underlying statistical distributions, and the approach allows the data set itself to define the groupings within, something appropriate for the examination of CMIP5 rainfall and evaporation distributions.

The resulting outputs of the soms analyses require interpretation, and that interpretation may differ between analysts. For that reason all direct results from the analyses have been presented within this report within separate documents for each Domain in order that the interpretations offered might be assessed by the reader and alternate interpretations taken where appropriate. Note that the soms are calculated using data from all three sub-periods across the 21st Century within a single analysis as the objective is to identify pathways of climate change through the coming Century and not just for the individual sub-periods separately.

An example is provided in Figure 2 and Table 2a for soms results from analysing temperature and rainfall changes under RCP4.5 within the full CMIP5 data set for a region in southern Africa using projected annual values (in this current report for the Orange-Senqu Basin precipitation minus evaporation is used rather than just precipitation, but this makes no difference to the interpretation). It may be worth noting that in an earlier report the viability of using soms on a large geographical scale, such as over southern Africa as a whole, as opposed to focusing on a region of limited size was examined. The outcome of that assessment was that a large-scale analysis potentially blurs information likely important on a smaller scale, and the current recommendation is that soms analyses are run over restricted geographical regions across which there is a reasonably consistent rainfall climatology in terms both of annual averages and of the seasonality of the rainfall. In the current report on the Orange-Senqu Basin it would have been possible to undertake a single analysis for the entire Basin but, with substantial differences in annual totals and in the timing of the season across the Basin, four independent regional analyses have been made. The region used in the analysis below also was consistent with these recommendations.

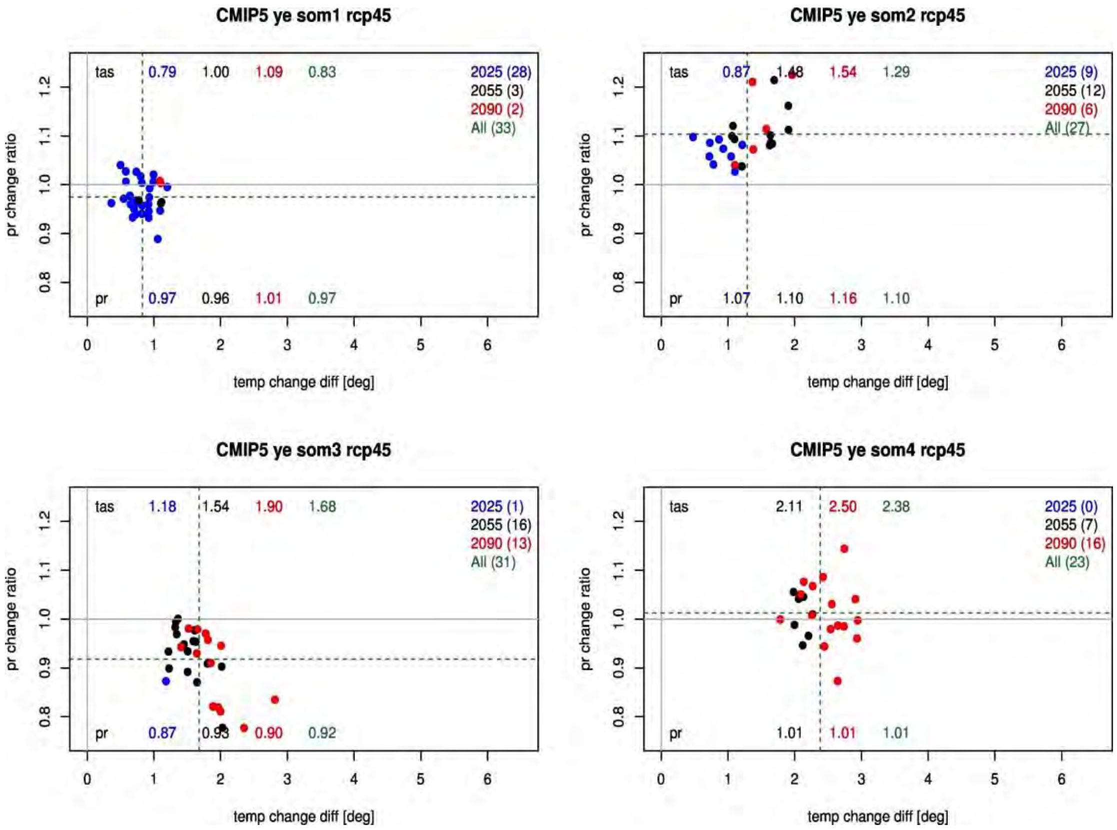


Figure 14. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the full rainfall season (Nov to Apr) under RCP4.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall/temperature projection from a single model, with projections centred on 2025 in blue, on 2055 in black, and on 2090 in red. Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot.

Table 2a. Scenarios for the full rainfall season (Nov to Apr) under RCP4.5 based on Figure 2 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are given to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2025	2055	2090
50	1→3	0.75ºC/0.95	1.50ºC/0.95	2.00ºC/0.90
30	1→4	0.75ºC/0.95	1.75ºC/1.00	2.50ºC/1.00
20	1→2	0.75ºC/1.00	1.50ºC/1.10	1.50ºC.1.15

Summary: With most of the 2025 projections within som1, and the majority of the rest for the other time slots elsewhere, three scenarios are identified all beginning in som1; the sequence of likelihoods is in the correct order but probably closer than indicated in column 1. Highest likelihood is for s decrease in rainfall, followed by a warmer scenario with no change, and a cooler one with an increase.

There are four charts, a number we selected *a priori* – a different number could have been selected, and that might have changed the results a little, but on balance from various tests four seems a reasonable choice for a data set of this size. The charts are numbered in the discussion following as 1 to 4 (reflected as som1 etc. in the individual chart headers in Fig. 2), sequentially top left (1), top right (2), bottom left (3), then bottom right (4), but note that there is no significance in this numbering and that the position of any of the four charts provides *no* indication of importance or of any other factor. However it is assumed that the more likely groupings contain the greater number of dots, each of which represents the combined projections of temperature and rainfall changes from an individual model colour coded according to the central year of each sub-period in this analysis, 2025 (blue), 2055 (black) or 2090 (red). Along the horizontal axis is the temperature change from the 1986 to 2005 average in °C while along the vertical axis is the rainfall change as a ratio with that in 1986 to 2005, i.e. a value of 1.0 indicates no change in annual rainfall total while a value of 1.5 (0.5) suggests an increase (a decrease) of 50%. Note that all changes are provided in relative terms, an approach that allows for the fact that most models may not provide precise simulations of local climates.

A couple of straightforward conclusions can be drawn immediately from Figure 2. First, all of the models, without exception, project increased temperatures throughout the 21st Century to a greater or lesser extent. Secondly, there is notable variability in the rainfall changes projected, with some projections suggesting increases of up to 20%, and others equivalent decreases, by the end of the Century. Were the average of all these rainfall projections to be taken, a standard approach (see Appendix 1), then the outcome would likely be around "no change", but it is quite clear that many projections in Figure 2 suggest substantial increases or decreases in future rainfall. With a soms analysis the question is addressed whether these more extreme projected increases and decreases are supported by a relatively high number of projections.

The following interpretation of Figure 2 might change according to the individual undertaking the work, but it is unlikely to change significantly. The following level of detail is not provided for the soms analyses in the main report, although the process and its presentation is the same. In this particular case three possible scenarios have been identified, although in the majority of cases studied previously only two tend to be identified; it is not impossible, however, for the result also to be one or four scenario(s). The recommended scenarios have been summarised in the Table below the diagram, below which is a brief summary of the rationale employed.

In this particular case most of the 2025 projections reside within a single som, number 1. Ignoring the few 2025 points in other soms and the similarly few points from other sub-periods in som1, then the interpretation offered is that there is reasonable agreement amongst the projections for the 2025 sub-period, certainly when compared with those for the two later sub-periods. From the 2055 sub-period on the projections fan out into three groups according to this analysis, certainly in terms of the rainfall projections: in som2 all projections suggest increased future rainfall, in som3 decreased rainfall, while in som4 are projections averaged around little change in rainfall. The recommended scenarios in the Table are based on these three options, with listed values of temperature and rainfall changes roughly based on the average values for each group (given in each diagram).

In this assessment, based on state-of-the-art climate models, each of the three outcomes is quite plausible, with no reasonable way in which a selection might be made. That said, the consequences for river basin management of each of the three outcomes might be substantial, as is the danger of maladaptation should an incorrect selection be made. To assist interpretation, it is recommended that sensitivity analyses be made for all options identified in the soms analyses in the expectation that the issue might be simplified by reducing the number of options through eliminating those with similar impacts, a step beyond the work reported in this report. To offer preliminary assistance, estimates of likelihoods for each of the recommended scenarios are given in the Table based on the *tentative* assumption that the more heavily populated soms are the more likely – population sizes are listed in each diagram to facilitate these estimates. So, in this particular case, the recommended scenario with assumed highest likelihood sees temperature increases up to about 2ºC with about a 10% reduction in annual rainfall, that with the next highest likelihood is a little warmer but with little change in rainfall, while a third cooler scenario with rainfall increasing by perhaps 15% might also be considered.

It is worth repeating that others may interpret the charts in Figure 2 differently to the manner outlined above. All CMIP5 projections are illustrated in Figure 2 and thus a selection of individual projections might be made, although this is not recommended as a general approach. But an example of a worthwhile selection might be: within a sensitivity analysis it might be useful to assess the recommended scenarios against some of the extreme individual projections, such as (based on Figure 2) a temperature increase of say 2.5ºC with a rainfall increase of 15% (from som2) or alternatively 3ºC and a reduction of 15% (from som3).

More typical than the three-scenario outcome discussed above is a two-scenario recommendation. As a rule this results when rainfall increases within two of the soms and decreases in the other two, the assumption being that the pathways are best defined under the assumption of a consistent direction of change in the rainfall within each projection.

Appendix 3. Scenarios used by the IPCC

The IPCC has used a number of greenhouse gas (GHG) scenarios during the course of the five Assessment Reports to date, reflecting the state of the science at each stage. First projections, including before the IPCC commenced work, simply used two model runs, one with GHG set at historical values, the second with a doubling of that value. Models were then run over sufficiently long periods to achieve climatic steady state and differences between the two runs assessed. A slightly more sophisticated approach was to increase GHG concentrations by 1% per year. Both approaches were required in order that projections might be made in lieu of any information at that time on possible future GHG concentrations, but both are still in use as straightforward methods to inter-compare models and to assess the impacts of changes in model formulations.

The first attempts at a more realistic view of future GHG concentrations were prepared for the First Assessment Report of 1990 – SA90 (Scenario A 1990), SB90, SC90 and SD90, the latter three being modifications around the Business-As-Usual estimate of SA90 on which most modelling research was focused (for pragmatic reasons – limitations of computer time). An improved set was developed for the Second Assessment Report – IS92a, IS92b, …, IS92f (IPCC Scenario 1992a, etc.,), but it was in preparation for the Third Assessment Report that a major step forward was made through developing storylines quantified through the use of Integrated Assessment Models (complex computer models covering industry, commerce, population, etc., with relatively simple climate modules) published in 2000 in the Special Report on Emissions Scenarios (SRES). The main SRES Scenarios are shown in the second table below, which includes a brief summary of the related storylines. In principle highest emissions are to be expected under A2, in which the objective is to promote economic growth within a competitive environment (regional decision making) as opposed to B1, lowest emissions, with globally-coordinated decision making focussed on environmental protection. In practice emissions as assessed were greater under A1FI than under A2 through most of the 21st Century. Again, for reasons of limited computer time, most results reviewed in the Third Assessment focused on A1B, A2 and B1.

A new approach has been taken in the Fifth Assessment Report, in which Representative Concentration Pathways (RCPs) have been used; RCPs are based on future radiative properties of the atmosphere under various GHG concentrations but without an underlying storyline. Four RCPSs have been used, RCP2.6, RCP4.5, RCP6.0 and RCP8.5, progressively higher numbers indicating greater GHG concentrations. In straightforward terms:

- RCP8.5 is roughly equivalent to A1FI
- RCP6.0 is roughly midway between A2 and B1
- RCP4.5 is roughly equivalent to B1
- RCP2.6 introduces lower emissions than in any SRES Scenario, with net anthropogenic emissions ceasing by about 2070.

According to calculations based on CMIP5, net emissions must cease at some stage during the 21st Century if the 2°C target set by the UNFCCC (notwithstanding the 1.5ºC aspiration target) as defining dangerous anthropogenic interference in the climate system is not to be breached. Some views indicate that cessation should be achieved by 2050, somewhat earlier than under RCP2.6. As of the end of 2014 observations indicated that emissions were following most closely the curves of A1FI and RCP8.5, but there are signs that trends in emissions growth are starting to reverse since then.

There is no objective manner in which the 'optimal' scenario might be selected, much depending on international agreements and national actions. The pessimistic view, based on currently observed emissions, is that the higher scenarios are likely to be followed. The optimistic view is that negotiations under the UNFCCC will succeed in meeting the 2°C target, and thus RCP2.6 is the most appropriate on which to base planning (all SRES Scenarios are too high from the perspective of the 2°C target). No selection is made in this document, but a balanced view has been presented based on all scenarios as represented by the RCPs.

Table. Approaches taken sequentially in generating climate scenarios using Global Climate Models

CO_2 Doubling (Steady State simulations)	Early work and used in all Assessments as a basic test of models
1% increase in CO_2 per annum (Transient simulations)	Early work and used in all Assessments as a basic test of models
SA90 – Scenario A of 1990 (Business as Usual) (there was also SB, SC and SD)	First Assessment Report and its Supplement
IS92 – IPCC Scenario (there was IS92a to IS92f)	Second and Third Assessment Reports
SRES – Special Report on Emissions Scenarios (to 2100) (see Table below)	Third, Fourth and Fifth Assessment Reports
RCPs – Representative Concentration Pathways (to 2100, but have been extended to 2300)	Fifth Assessment Report

Table. Summary of the storylines used in the SRES Scenarios

SRES Scenario	Basis of storyline
A1FI (fossil fuel intensive) A1T (technology-based generation) A1B (balanced between fossil fuels and technology)	Global decision making; economic growth priority
A2	Regional decision making; economic growth priority
B1	Global decision making; environmental protection priority
B2	Regional decision making; environmental protection priority

Footnote: In CMIP6, currently under construction, a development of the RCP concept to include economic, social and environmental considerations has been introduced. One objective of a redesigned approach in the CMIP series is to ensure, as far as feasible, that projections in CMIP5 and onwards are compatible to the extent that they may form a growing 'super-ensemble'. CMIP6 will also include numerous coordinated model experiments other than the familiar global climate change projections. Thus in time CMIP6, already larger in terms of contributions of projections of global climate than CMIP5, should offer coordinated research with CMIP5 plus other focussed information.

Self-Organising Maps Results for the Waterberg Domain

Introduction. Results are presented below for the analyses through self-organising maps (soms) for the Waterberg Domain. Assessments of soms analyses for each RCP and temperature vs rainfall or temperature vs rainfall less evaporation are presented individually towards the end of this document; RCPs start at 2.6 and increase successively, temperature vs rainfall is presented before temperature vs rainfall less evaporation. Results from the soms are charted on each page followed by a table giving suggested scenarios from these particular results; a brief justification for the suggested scenarios is provided below each table.

Immediately following this introductory section is a collation of the results from the soms tables for easy reference. Below the collated table for each RCP is a further table giving, for each individual soms analysis, two suggested extreme scenarios, derived entirely subjectively. These extreme scenarios focus on changes to rainfall or to rainfall less evaporation as appropriate, and are an attempt to indicate possible scenarios representing greatest reasonable increases or decreases in rainfall or in rainfall less evaporation for that particular RCP. Note that had the focus been towards relatively high/low temperature increases different extreme scenarios would have been produced on at least some occasions. Thus the suggested extreme scenarios do not capture necessarily greatest and least changes in temperature projected for that RCP.

The number of projections for a given RCP, listed in the soms charts captions and repeated in the collation tables, may differ between the temperature against rainfall alone analyses and the temperature against rainfall less evaporation analyses for technical reasons.

Also provided following the tables of recommended scenarios for each RCP overall, and towards the end of this document for individual soms under each RCP, are results for the inter-annual variability (IAV) calculations. These illustrate future decadal probabilities that in successive two- and three-year periods:

- annual temperatures will exceed +2 and +3 standard deviations
- annual rainfall totals or rainfall less evaporation values will be below the 10th and 25th percentiles
- annual rainfall totals or rainfall less evaporation values will be above the 75th and 90th percentiles

relative to values across the base period of 1979-2005. Temperature probabilities have been presented only for the temperature vs rainfall soms as those for the temperature vs rainfall less evaporation soms are equivalent. Details of these charts are discussed further in the main document. Equivalent charts of IAV calculations for each RCP in total are provided immediately following the summary tables and before details of individual RCPs.

Summary of results.

Temperature against rainfall. As might be expected, temperatures in the RCP scenarios increase with emissions, a rise that is, in general, greater for the drier scenarios. Rainfall changes in both directions appear in all suggested scenarios for individual RCPs, although the marginally higher likelihoods in general are for little change in all except RCP8.5, for which the outstanding likelihood is for a decrease.

Temperatures in the recommended extreme scenarios increase in general with RCP; rainfall changes in the increased scenarios tend to be projected to be above current levels, but only by perhaps 5%, although more under RCP8.5. Decreases of rainfall in the extreme scenarios are somewhat larger than the corresponding increases.

Likelihoods of annual temperatures exceeding two and three standard deviations calculated across the base period of 1979-2005 increase, naturally, with RCP (see Figure WA), but vary also according to individual soms (see diagrams in the sections for the individual RCPs). Under RCP8.5 successive two and three year periods are almost certain by the 2070's for two standard deviations and by the 2080's for three standard deviations. By contrast, under RCP2.6 only one of the soms produces probabilities exceeding 80% (by the 2050's) for two standard deviations whether over two or over three year periods, whereas for three standard deviations probabilities peak for just one som at around 70%. For RCP4.5 100% probabilities are reached only by the end of the century and for RCP6.0 only marginally by perhaps the 2070's for a single som for two standard deviations over two years.

Likelihoods of annual rainfall totals outside the 10th and 90th percentiles over 2 and 3 years increase/decrease slightly respectively with high RCPs, in general being below 10% (see Figure WB). Similar increasing/decreasing trends of these likelihoods in time are in general apparent for all individual RCPs also, but there is also distinct differences in likelihoods for individual soms (see diagrams in the sections for the individual RCPs). For many soms likelihoods remain below 10% throughout but for certain ones these may rise towards 30% or higher.

Temperature against rainfall less evaporation. The picture is a little more complex for rainfall less evaporation. For both RCP2.6 and RCP4.5 there is an approximate 50-50 spilt in likelihoods for wetter (or at least little change) and drier conditions, although greater decreases than increases are projected; for both RCP6.0 and RCP8.5 the main signal is for a decrease in rainfall less evaporation, with substantial decreases possible at lower likelihoods.

Temperatures in the suggested extreme scenarios increase in general with RCP. Marked decreases in water availability are suggested in the decreased extremes scenarios for all RCPs, with some large increases possible also for RCP2.6 (perhaps in part because of the relatively small population of projections) and RCP8.5.

Likelihoods of annual rainfall less evaporation amounts outside the 10th and 90th percentiles over 2 and 3 years, as similarly for rainfall totals, do not change substantially, in general being below 10% but perhaps are increased above there towards the end of the century for the higher RCPs (see Figure WC). However there are increasing/decreasing respectively likelihoods of 2/3 year values outside the 25th and 75th percentiles as the century proceeds, again especially for RCP6.0 and RCP8.5 (see Figures in individual sections). There does seem to be a slight weighting towards greater likelihoods for below the 25th percentile than for above the 75th, i.e. a skewing towards drier conditions. For many soms likelihoods in either direction remain below 10% throughout, but for some they may reach 30%.

Conclusions. In section 3 of the main report it was noted that the Waterberg Domain sits on the western flank of higher ground in north-central South Africa at a location where all ensemble means for all RCPs suggest future rainfall decreases on all time scales, as do the majority of ensemble means for rainfall less evaporation. Yet, other than for RCP8.5, the higher likelihoods according to the soms analyses are for slight increases in either rainfall or rainfall less evaporation, or for little change. The reason is clear in the soms analyses, that the full sets of ensembles are skewed towards drier conditions such that the ensemble means are weighted against the substantial numbers of projections for relatively limited increases.

Across RCP2.6, RCP4.5 and RCP6.0 there is some consistency between suggested scenarios in terms of adjustments in rainfall and in rainfall less evaporation notwithstanding small increases in temperature with rising emissions. As found in most other areas for which the soms technique has been applied RCP8.5 stands out somewhat, both in terms of higher temperature increases as well as in adjustments to rainfall/rainfall less evaporation which tend to be more substantially negative. Hence the recommendations below are weighted away from RCP8.5. Overall the recommendations suggest approximately slightly higher prospects of increased over decreased water availability according to both analyses. However, decreases in water availability according to the rainfall less evaporation assessments might be more significant than under the rainfall alone assessments, as the former take into consideration increased evaporation as temperatures rise.

If there is a requirement to examine projected changes under RCP8.5 then use the recommended and extreme scenarios repeated from the appropriate collated tables below.

The IAV calculations indicate steady increases in time in likelihoods of extended 2- and 3-year spells of temperatures above historical annual 2 and 3 standard deviations, greater with higher RCPs and reaching 100% in many cases towards the end of the century. Both for rainfall and for rainfall less evaporation likelihoods of extended 2- and 3-years spells below and above historical annual 10th and 90th percentiles do not change significantly in time, but those for the 25th and 90th percentiles do (although not for all soms), especially for RCP6.0 and RCP8.5, suggesting an increase in spread of annual values with possible slight bias towards drier conditions

.

Recommended Scenarios for the Waterberg Domain based on RCP2.6, RCP4.5 and RCP6.0

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
55	1.00ºC/1.00	1.75ºC/1.00	2.00ºC/1.00
45	1.00ºC/0.95	2.00ºC/0.95	2.75ºC/0.90

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall changes)

	2040	2065	2080
Increased	1.00ºC/1.05	1.75ºC/1.05	2.25ºC/1.05
Decreased	1.50ºC/0.90	2.00ºC/0.85	2.25ºC/0.85

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
60	1.25ºC/1.00	1.75ºC/1.05	2.00ºC/1.05
40	1.50ºC/0.80	2.00ºC/0.70	2.50ºC/0.60

Extreme scenarios based on temperature against rainfall less evaporation analyses (focussed primarily on rainfall less evaporation changes)

	2040	2065	2080
Increased	1.00ºC/1.10	2.00ºC/1.10	2.50ºC/1.10
Decreased	1.50ºC/0.60	2.00ºC/0.60	2.75ºC/0.60

Recommended Scenarios for the Waterberg Domain based on RCP8.5

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
60	1.75ºC/0.95	3.00ºC/0.90	5.50ºC/0.80
40	1.75ºC/0.95	3.00ºC/1.00	4.75ºC/0.95

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall changes)

	2040	2065	2080
Increased	1.25ºC/1.10	2.00ºC/1.10	4.50ºC/1.10
Decreased	1.75ºC/0.85	3.25ºC/0.80	5.25ºC/0.75

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
90	1.75ºC/0.85	3.25ºC/0.85	5.00ºC/0.70
10	1.75ºC/0.90	2.75ºC/1.50	5.25ºC/1.80

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall less evaporation changes)

	2040	2065	2080
Increased	1.75ºC/1.40	2.75ºC/1.50	4.25ºC/1.50
Decreased	1.50ºC/0.75	3.25ºC/0.70	5.00ºC/0.60

Scenarios from each RCP for the Waterberg Domain based on analyses of temperature against rainfall to the left and on analyses of temperature against rainfall less evaporation to the right; in the summaries following each table TR refers to the temperature/rainfall table to the left and TRLE to the temperature/rainfall less evaporation table to the right. Following the RCP header are the numbers of projections available to produce TR and TRLE respectively. Note that the soms numbers in the second columns of each individual table are arbitrary and should not be used to inter-compare TR and TRLE.

RCP2.6 – 20 and 18 projections

	%		2040	2065	2080		%		2040	2065	2080
1	45	4	1.00ºC/1.00	1.00ºC/1.00	1.00ºC/1.00		40	1	1.00ºC/1.00	1.00ºC/1.00	1.10ºC/1.00
2	25	2	1.50ºC/0.95	1.50ºC/1.00	1.50ºC/0.95		35	2	1.50ºC/0.85	1.50ºC/0.80	1.50ºC/0.75
3	15	3	1.75ºC/0.90	2.25ºC/0.90	2.25ºC/0.95		15	4	2.00ºC/0.60	2.00ºC/0.55	2.00ºC/0.75
4	15	1	1.25ºC/0.90	1.50ºC/0.90	1.50ºC/0.90		10	3	2.00ºC/1.30	2.25ºC/1.45	2.00ºC/2.00

Summary: According to the TR scenarios a decrease in water availability is perhaps the most likely future in this Domain. From TRLE, on the other hand, there is a rough balance between increased and decreased rainfall less evaporation likelihoods.

Suggested extreme scenarios for RCP2.6 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	0.75ºC/1.05	1.00ºC/1.05	1.00ºC/1.05		1.00ºC/1.30	2.00ºC/1.30	2.00ºC/1.50
Decreased	1.50ºC/0.90	2.00ºC/0.90	2.00ºC/0.90		1.00ºC/0.60	1.50ºC/0.60	2.00ºC/0.60

RCP4.5 – 38 and 32 projections

	%		2040	2065	2080		%		2040	2065	2080
1	55	2→3	1.25ºC/1.00	2.00ºC/1.00	2.50ºC/1.00		60	1→3	1.25ºC/1.00	2.00ºC/1.10	2.00ºC/1.05
2	45	1→4	1.50ºC/0.95	2.50ºC/0.95	2.75ºC/0.90		40	2→4	1.50ºC/0.50	2.75ºC/0.60	3.00ºC/0.90

Summary: While TR is roughly split between little change and a decrease in rainfall the weight in TRLE is towards increased rainfall less evaporation.

Suggested extreme scenarios for RCP4.5 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080

Increased	1.00ºC/1.05	2.00ºC/1.05	2.50ºC/1.05		1.00ºC/1.10	2.00ºC/1.10	3.00ºC/1.10
Decreased	1.25ºC/0.85	2.00ºC/0.85	3.00ºC/0.85		1.50ºC/0.60	2.50ºC/0.60	3.00ºC/0.50

RCP6.0 – 15 and 12 projections

	%		2040	2065	2080		%		2040	2065	2080
1	55	2→3	1.25ºC/1.00	2.00ºC/1.00	2.75ºC/1.00		60	1→3	1.25ºC/0.95	2.00ºC/1.05	2.50ºC/0.90
2	45	1→4	1.50ºC/0.95	2.25ºC/0.95	3.25ºC/0.90		40	2→4	1.25ºC/0.50	2.75ºC/0.30	3.50ºC/0.30

Summary: One of the more notable aspects of this to be taken into consideration is the relatively small number of projections available, which gives relatively less confidence in these results. Nevertheless highest likelihood in both cases is for any reductions to be limited, more so in TR. The substantial reduction suggested by the lower-likelihood TRLE scenario needs to be treated with caution.

Suggested extreme scenarios for RCP6.0 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.00ºC/1.05	1.75ºC/1.05	2.25ºC/1.05		1.25ºC/1.05	2.00ºC/1.05	2.25ºC/1.10
Decreased	1.50ºC/0.85	2.00ºC/0.90	2.50ºC/0.80		1.25ºC/0.60	2.25ºC/0.50	2.75ºC/0.50

RCP8.5 – 40 and 34 projections

	%		2040	2065	2080		%		2040	2065	2080
1	60	1→2→4	1.75ºC/0.95	3.00ºC/0.90	5.50ºC/0.80		90	1→3→4	1.75ºC/0.85	3.25ºC/0.85	5.00ºC/0.70
2	40	1→3	1.75ºC/0.95	3.00ºC/1.00	4.75ºC/0.95		10	1→2	1.75ºC/0.90	2.75ºC/1.50	5.25ºC/1.80

Summary: undoubtedly the weight of these scenarios is for reductions in rainfall and in rainfall less evaporation. A small number of the TRLE simulations suggest high increases in rainfall less evaporation, but there must be a suspicion that this results in part from relatively small differences between these values in the base period.

Suggested extreme scenarios for RCP8.5 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.25ºC/1.10	2.00ºC/1.10	4.50ºC/1.10		1.75ºC/1.40	2.75ºC/1.50	4.25ºC/1.50
Decreased	1.75ºC/0.85	3.25ºC/0.80	5.25ºC/0.75		1.50ºC/0.75	3.25ºC/0.70	5.00ºC/0.60

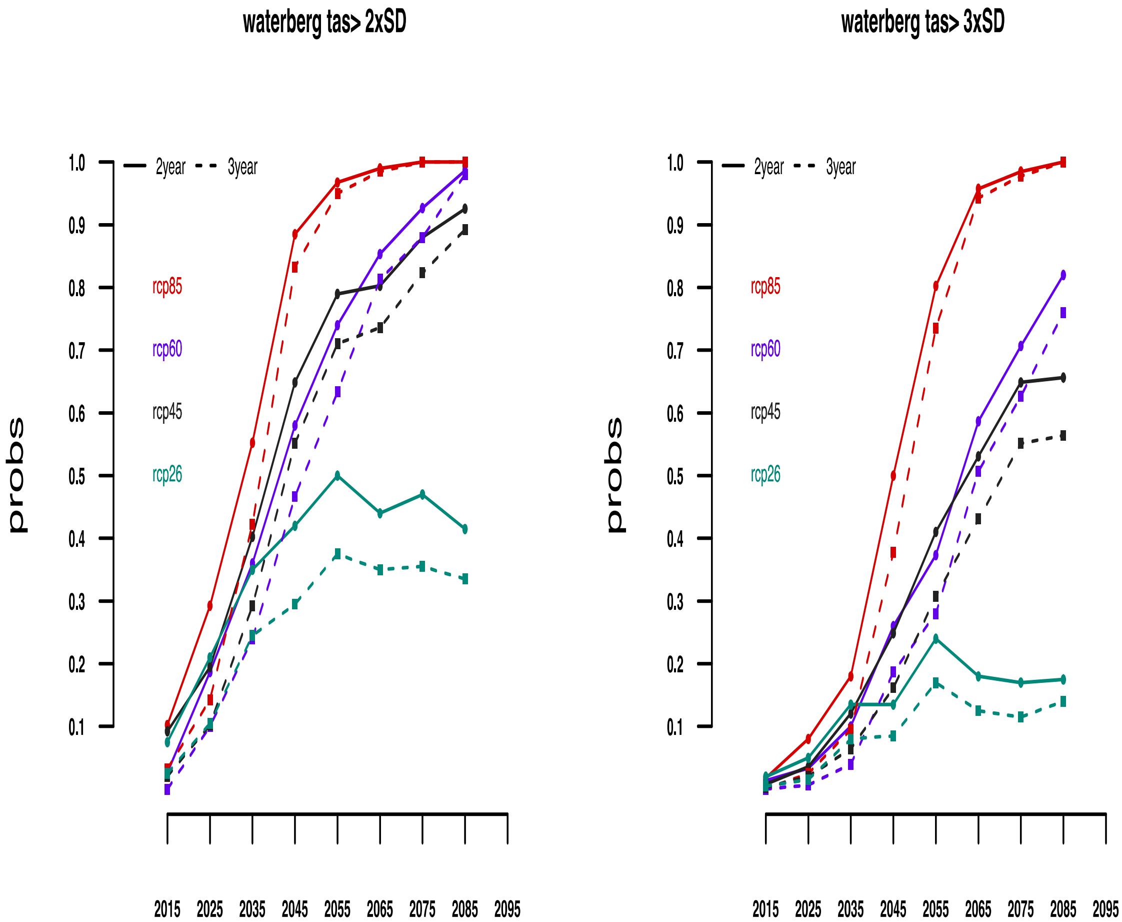


Figure WA. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes.

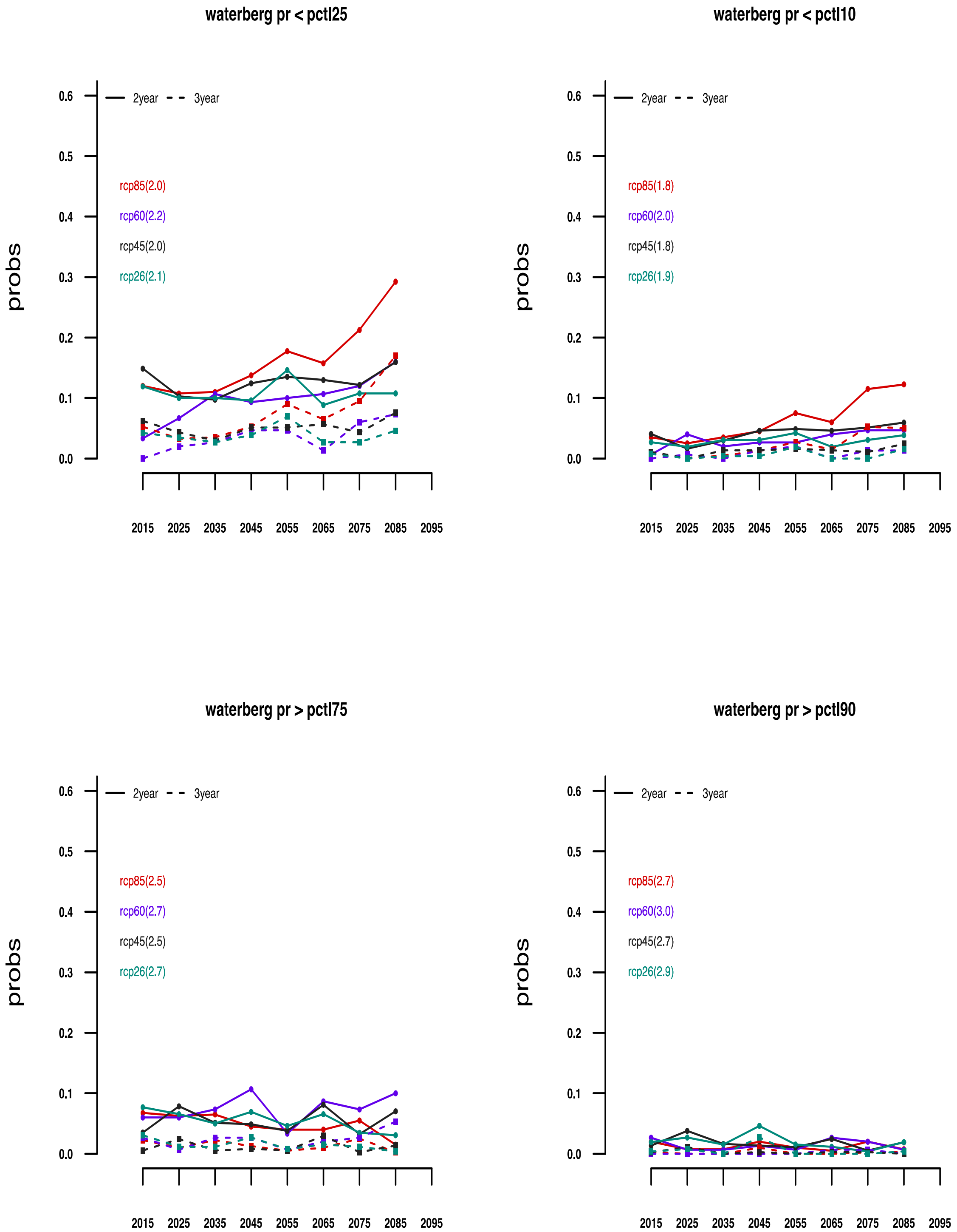


Figure WB. Decadal probabilities that future annual rainfall totals will be below the 25th percentile (top left) or the 10th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the RCP numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

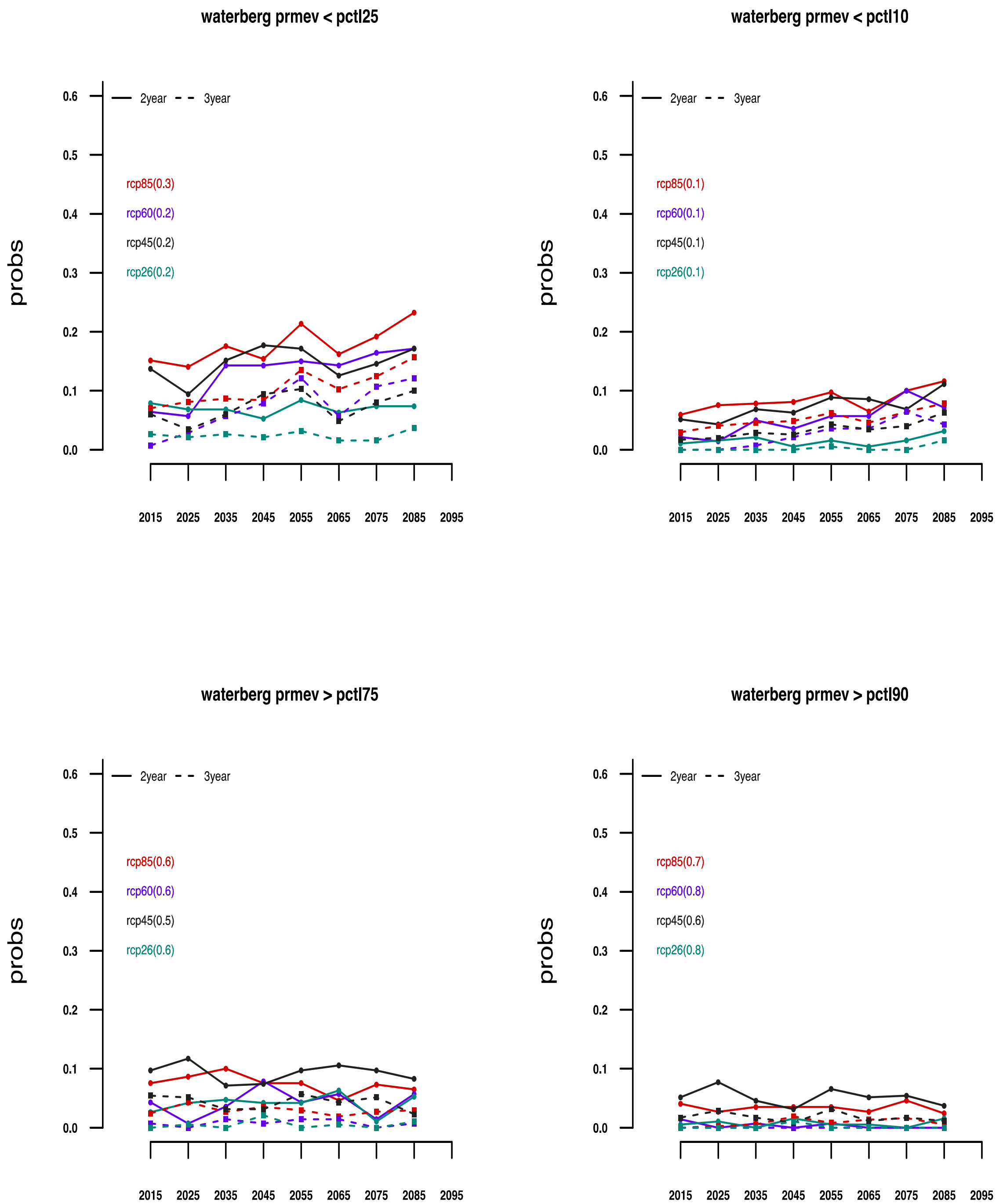


Figure WC. Decadal probabilities that future annual rainfall less evaporation totals will be below the 25th percentile (top left) or the 10th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the RCP numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP2.6; temperature vs rainfall

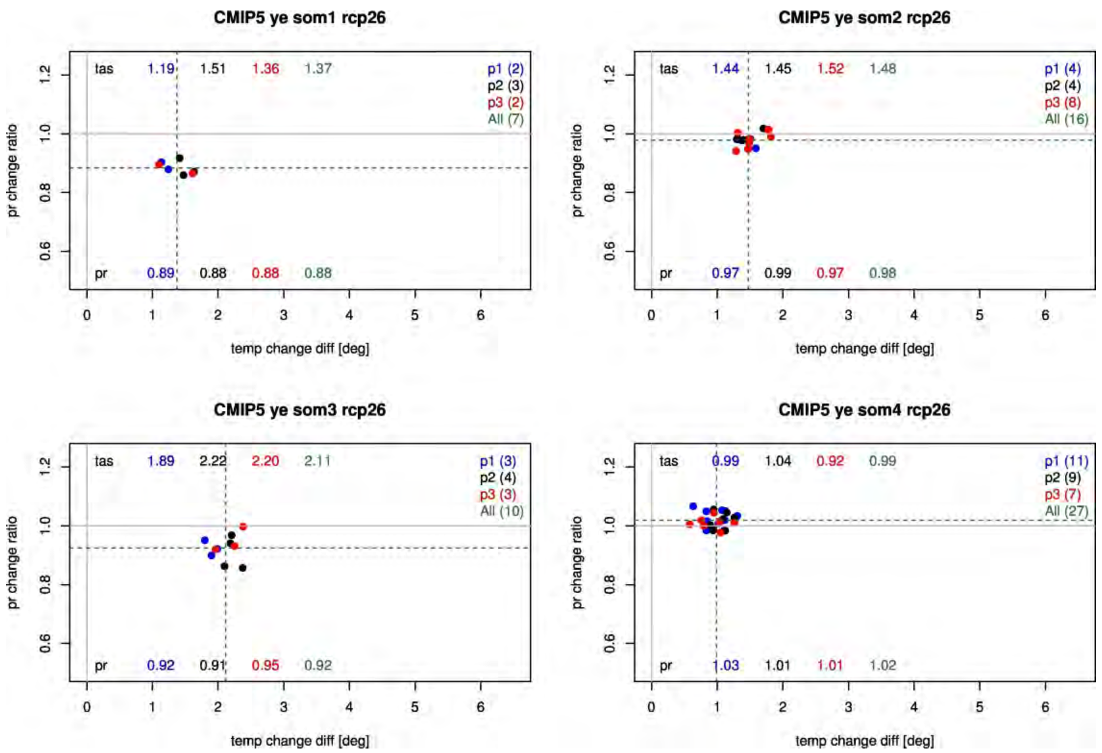


Figure WD1. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Waterberg Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 20 projections available in CMIP5 for RCP2.6.

Table WD1a. Scenarios for the year over the Waterberg Domain under RCP2.6 based on Figure WD1 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
45	4	1.00ºC/1.00	1.00ºC/1.00	1.00ºC/1.00
25	2	1.50ºC/0.95	1.50ºC/1.00	1.50ºC/0.95
15	3	1.75ºC/0.90	2.25ºC/0.90	2.25ºC/0.95
15	1	1.25ºC/0.90	1.50ºC/0.90	1.50ºC/0.90

Summary: Each som appears to form an individual pathway, with highest likelihood towards minimal change in rainfall. Overall there is a rough 70/30 split in likelihoods between little change (soms 1 and 2) and decreased (soms 3 and 4) in rainfall. Temperature increases are higher in general for the drier scenarios.

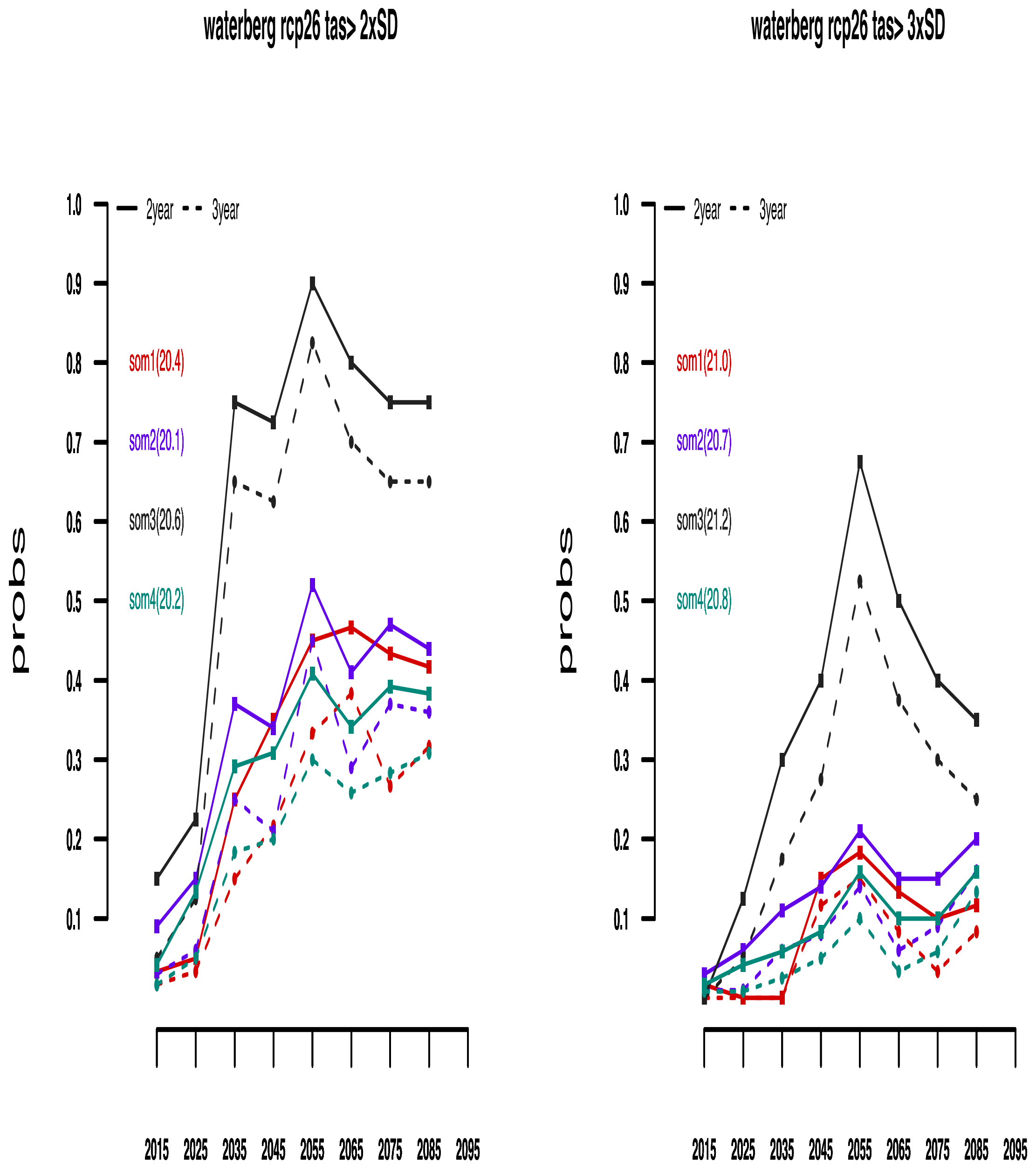


Figure WD15. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD1 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP2.6; temperature vs rainfall

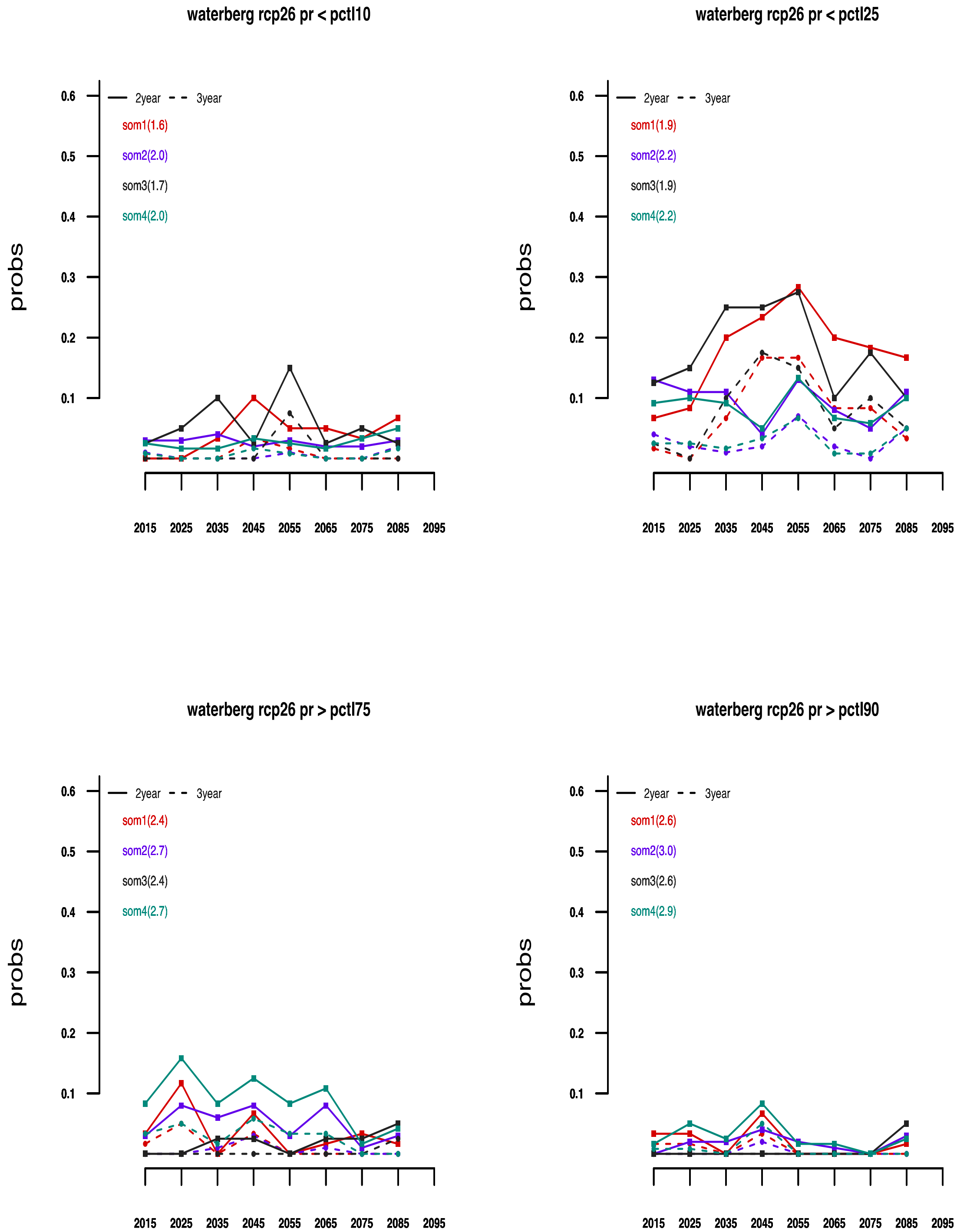


Figure WD16. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD1 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

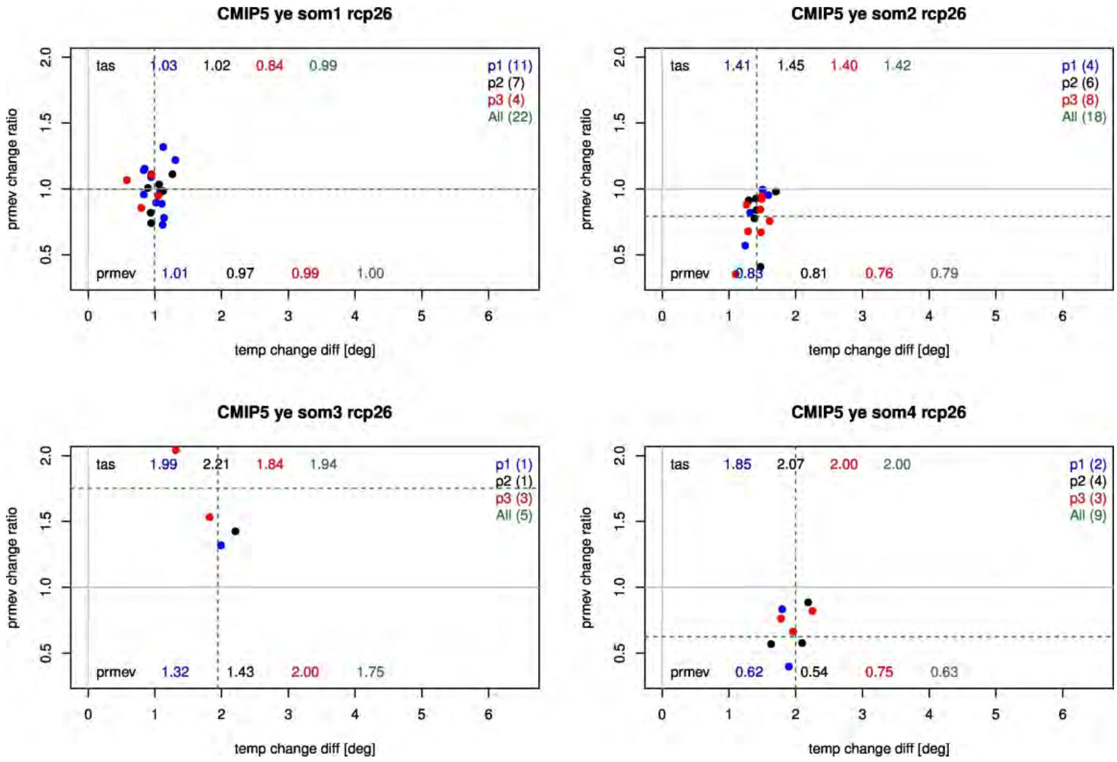


Figure WD4. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Waterberg Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 18 projections available in CMIP5 for RCP2.6.

Table WD2a. Scenarios for the year over the Waterberg Domain under RCP2.6 based on Figure WD4 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
40	1	1.00ºC/1.00	1.00ºC/1.00	1.10ºC/1.00
35	2	1.50ºC/0.85	1.50ºC/0.80	1.50ºC/0.75
15	4	2.00ºC/0.60	2.00ºC/0.55	2.00ºC/0.75
10	3	2.00ºC/1.30	2.25ºC/1.45	2.00ºC/2.00

Summary: Four scenarios with each som producing its own pathway. A roughly equal split of likelihoods between a decrease in rainfall less evaporation (soms 2 and 4) and no change or an increase (soms 1 and 3). One projection sits on its own (som 3) with a substantial increase in rainfall less evaporation.

RCP2.6; temperature vs rainfall less evaporation

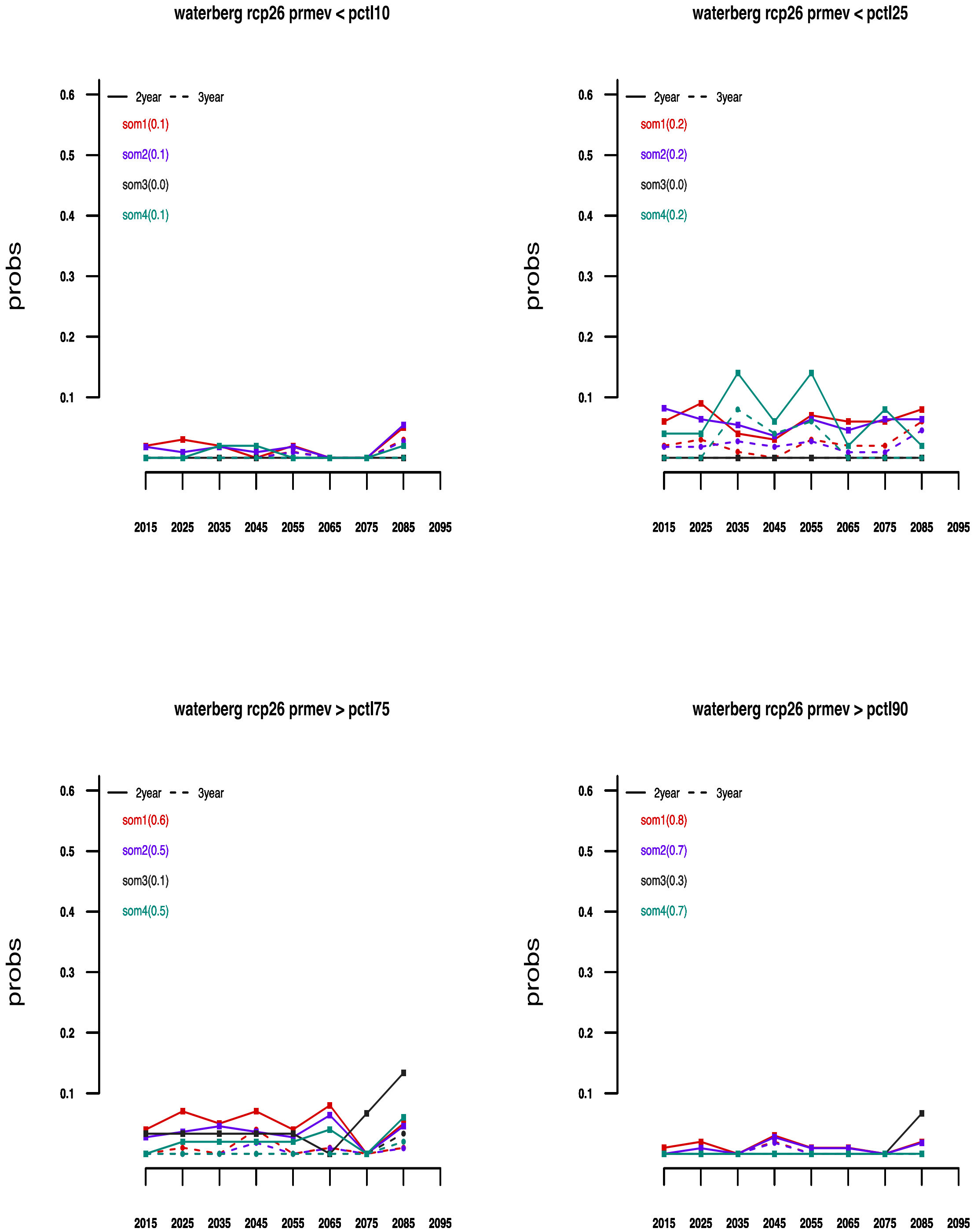


Figure WD17. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD3 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall

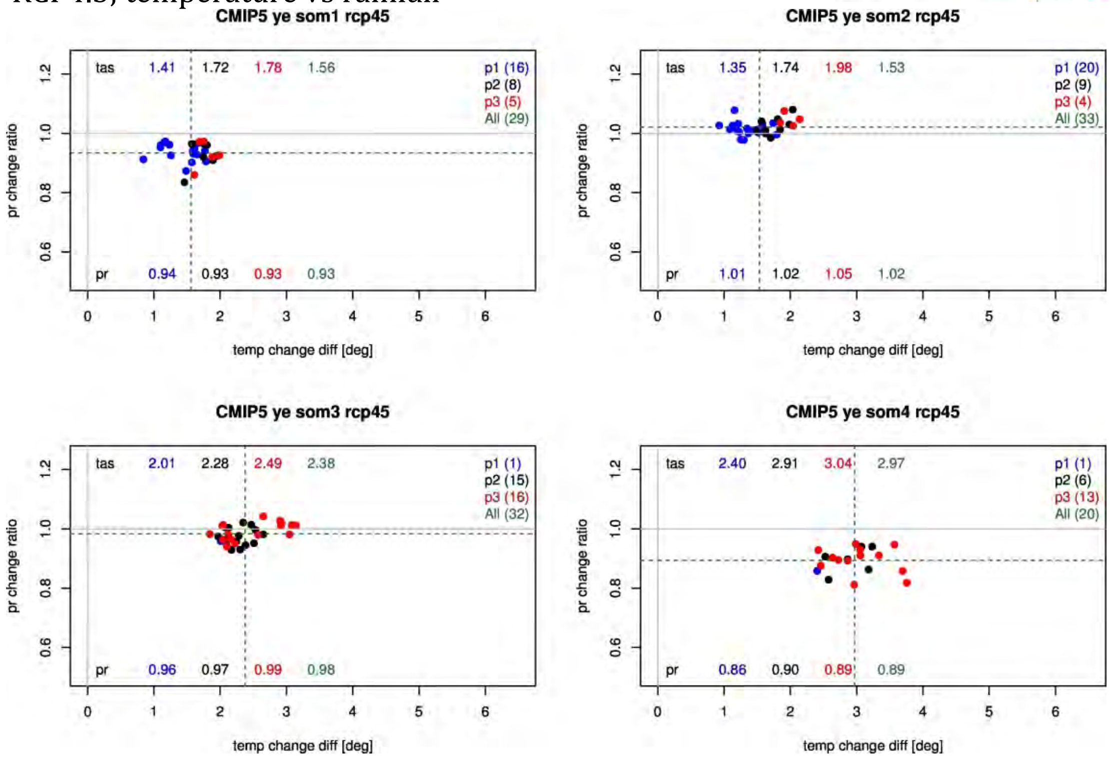


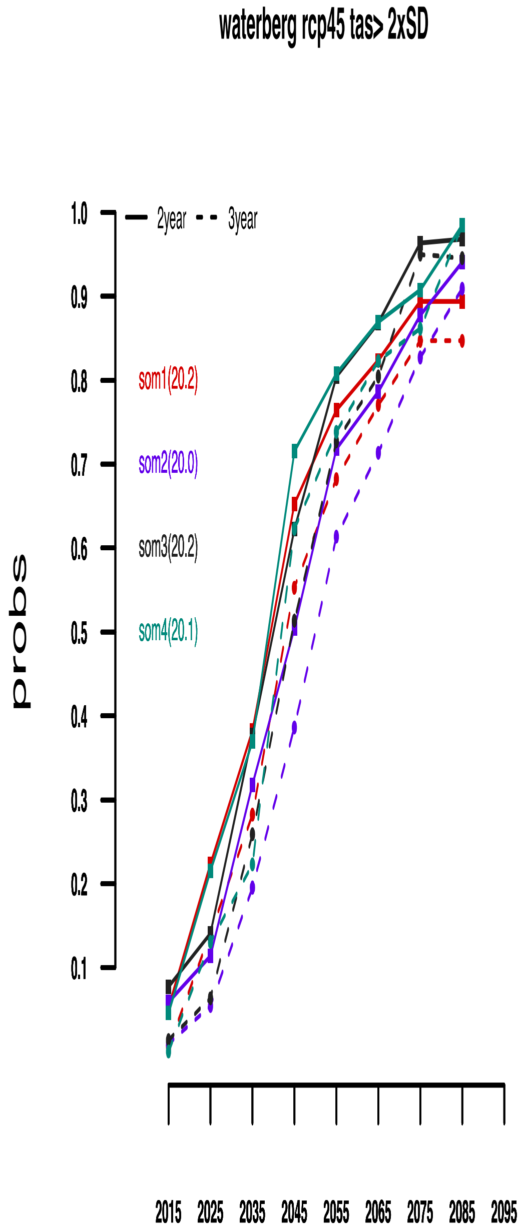
Figure WD6. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Waterberg Domain under RCP4.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 38 projections available in CMIP5 for RCP4.5.

Table WD3a. Scenarios for the year over the Waterberg Domain under RCP4.5 based on Figure WD6 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
55	2→3	1.25ºC/1.00	2.00ºC/1.00	2.50ºC/1.00
45	1→4	1.50ºC/0.95	2.50ºC/0.95	2.75ºC/0.90

Summary: Two scenarios with roughly equal likelihoods, perhaps the more likely being the cooler with little change in rainfall. Note that the second, warmer, drier, scenario includes an immediate drying which is maintained throughout.

RCP4.5; temperature vs rainfall



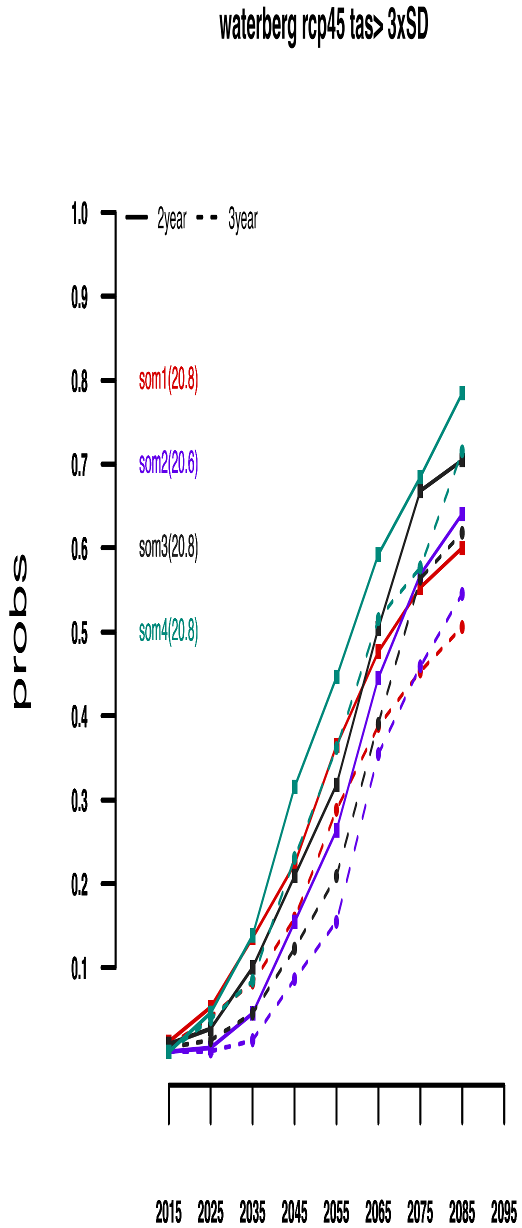


Figure WD7. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD6 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall

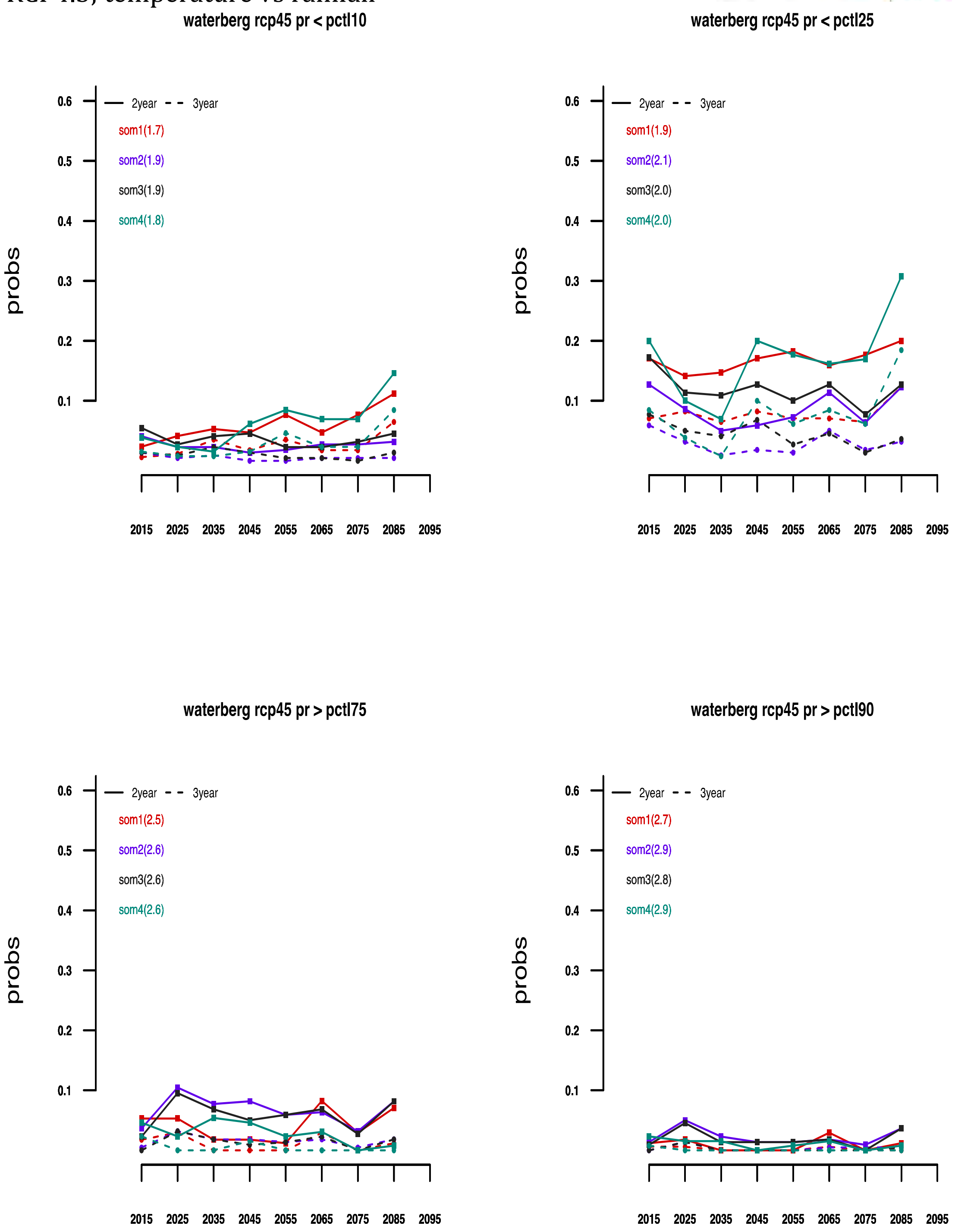


Figure WD8. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD6 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall less evaporation

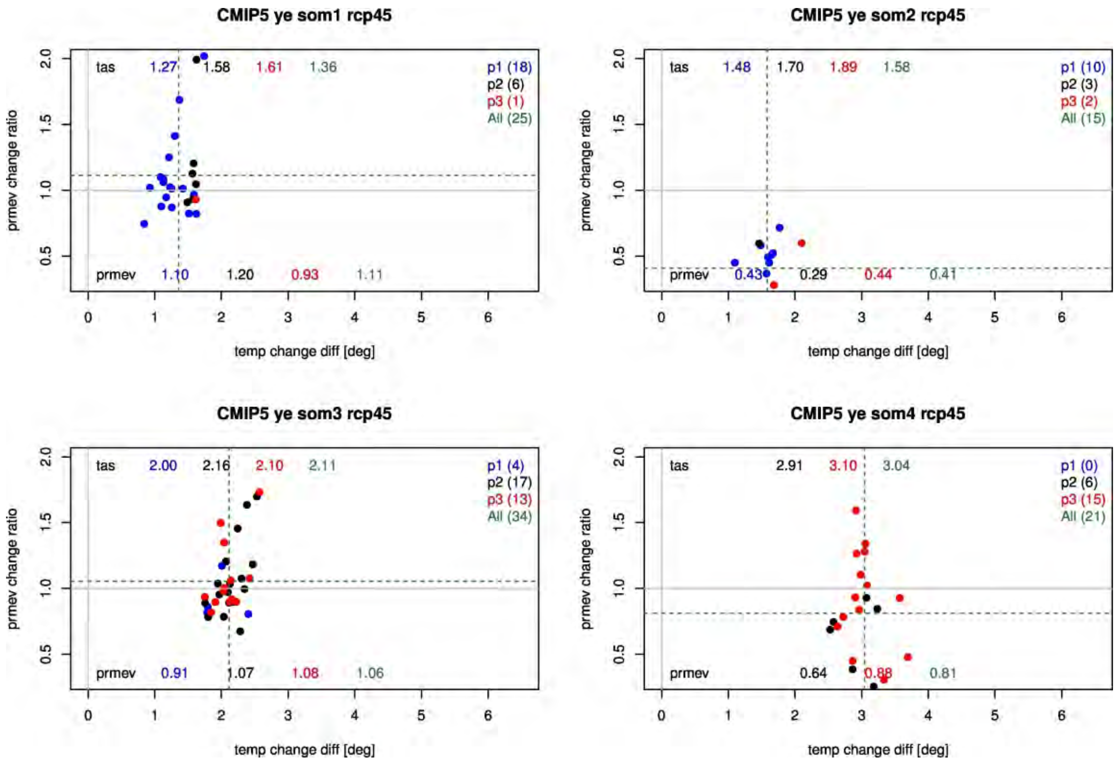


Figure WD9. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Waterberg Domain under RCP4.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 32 projections available in CMIP5 for RCP4.5.

Table WD4a. Scenarios for the year over the Waterberg Domain under RCP4.5 based on Figure WD9 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
60	1→3	1.25ºC/1.00	2.00ºC/1.10	2.00ºC/1.05
40	2→4	1.50ºC/0.50	2.75ºC/0.60	3.00ºC/0.90

Summary: Given that all projections were included in the calculations, including those with relatively small rainfall less evaporation values during the base period, the result is a number of projections with substantial positive and negative change in rainfall less evaporation; some attempt has been made to accommodate this factor in the interpretations. Either there will be little change in rainfall less evaporation, highest likelihood, or it will decrease significantly in the near term.

RCP4.5; temperature vs rainfall less evaporation

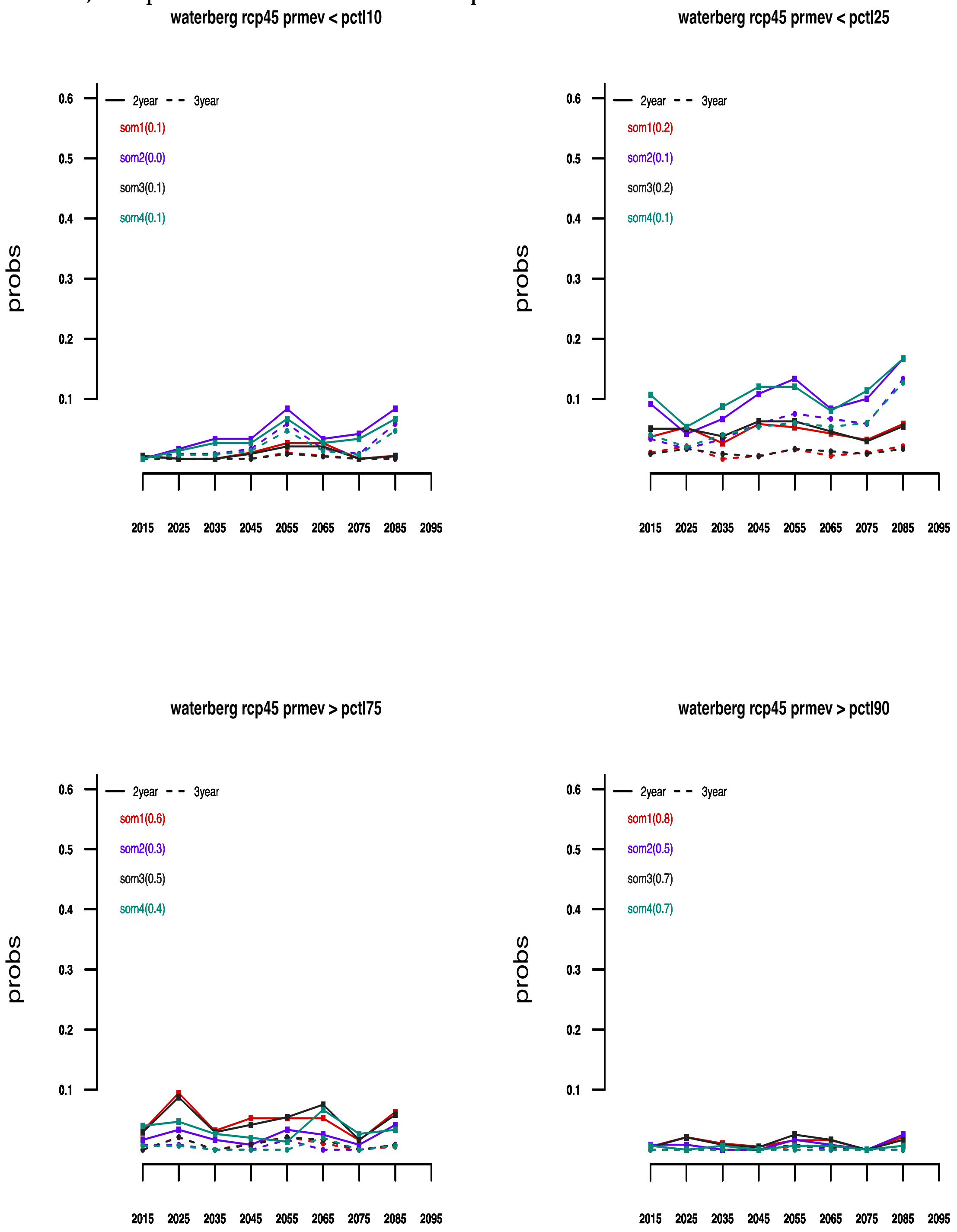


Figure WD10. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD9 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP6.0; temperature vs rainfall

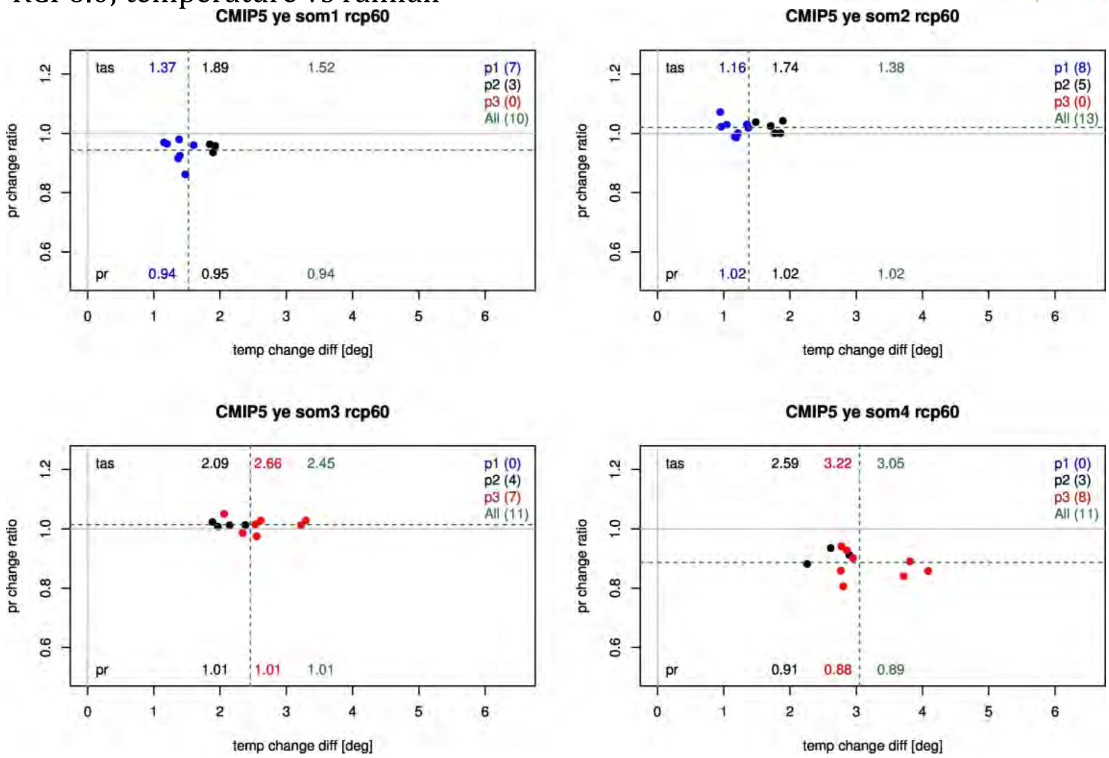


Figure WD11. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Waterberg Domain under RCP6.0 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 15 projections available in CMIP5 for RCP6.0.

Table WD5a. Scenarios for the year over the Waterberg Domain under RCP6.0 based on Figure WD11 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
55	2→3	1.25ºC/1.00	2.00ºC/1.00	2.75ºC/1.00
45	1→4	1.50ºC/0.95	2.25ºC/0.95	3.25ºC/0.90

Summary: Highest likelihood for little change in rainfall, with a decrease in the alternate warmer scenario.

RCP6.0; temperature vs rainfall

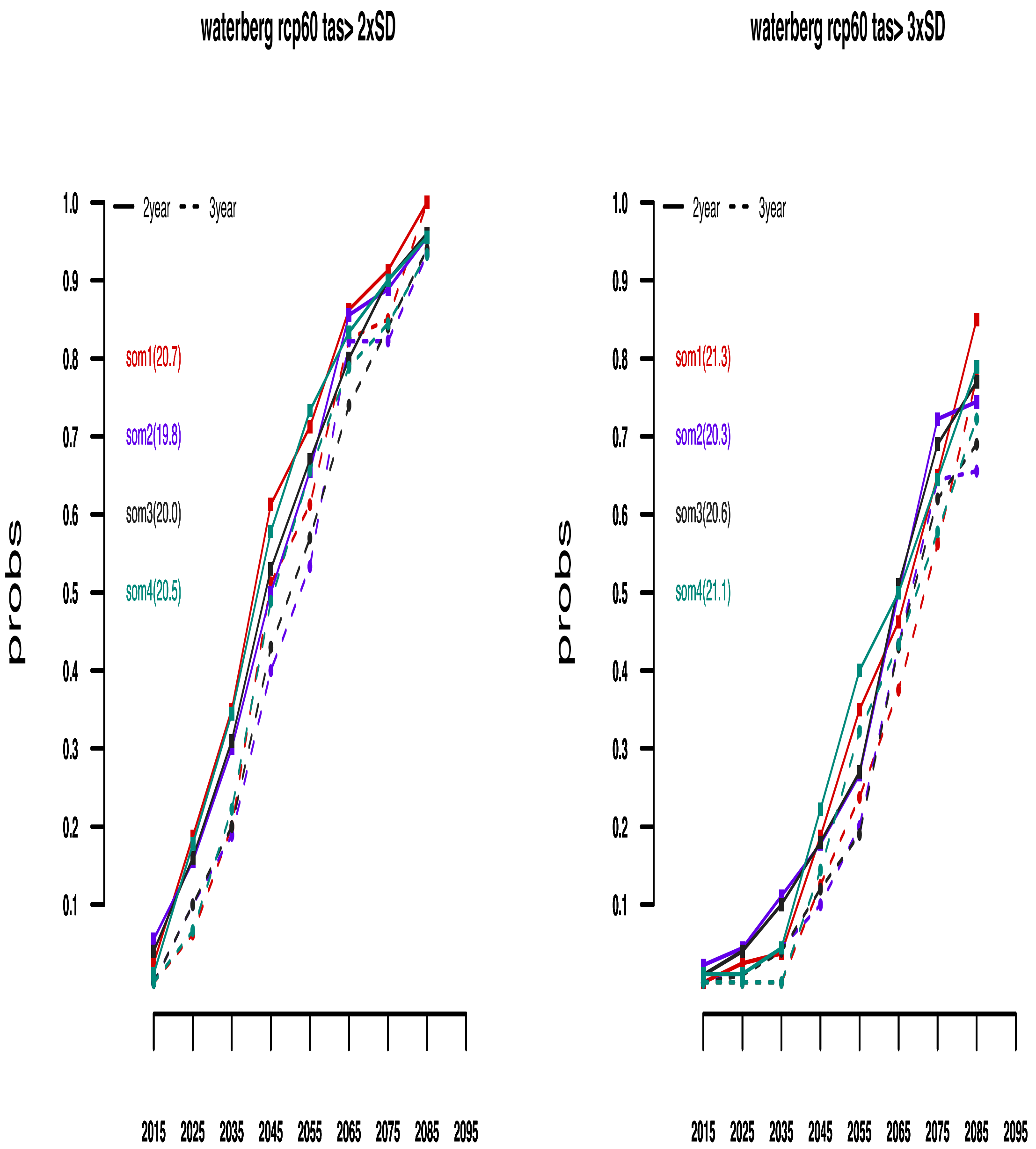


Figure WD12. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD11 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP6.0; temperature vs rainfall

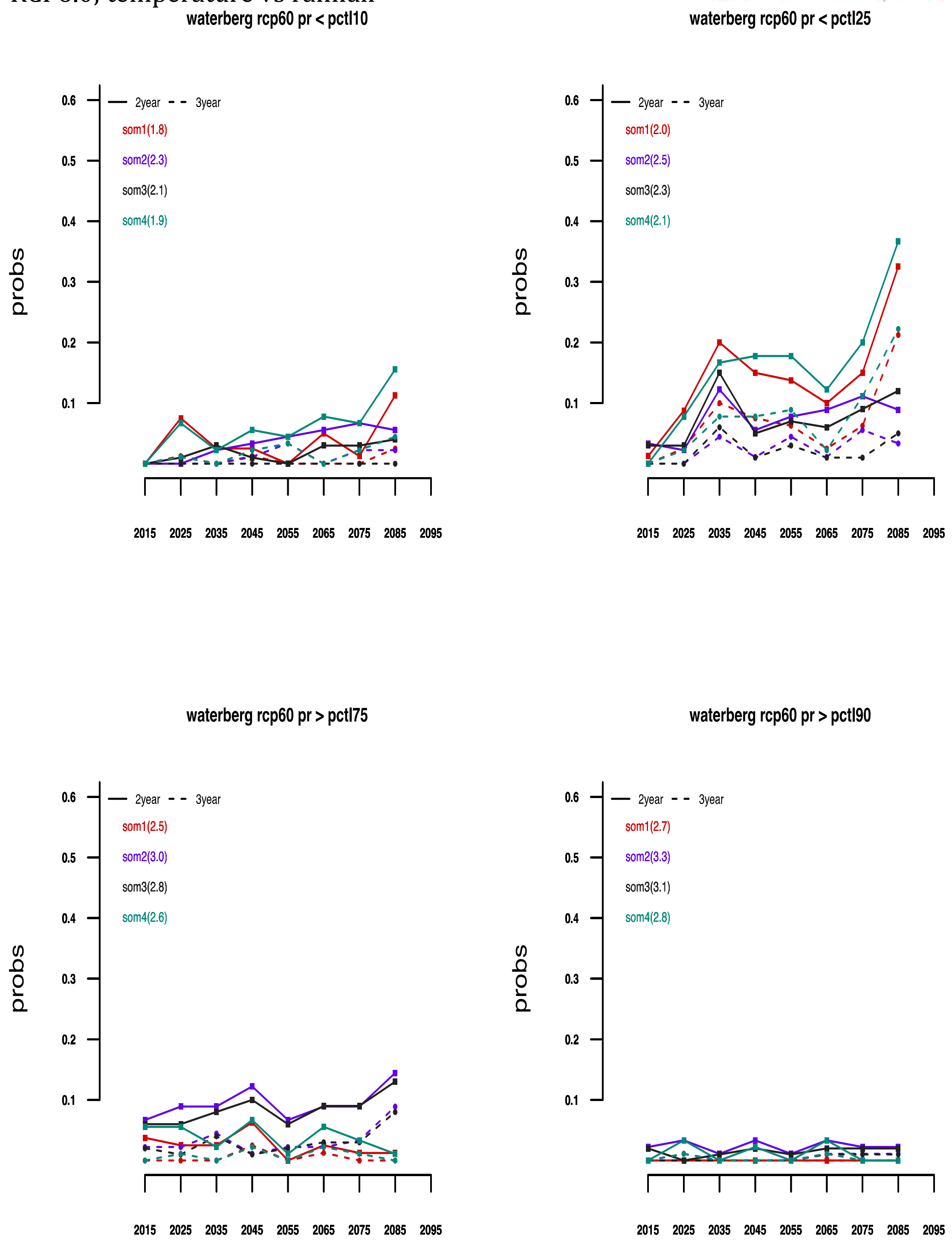


Figure WD13. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD11 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP6.0; temperature vs rainfall less evaporation

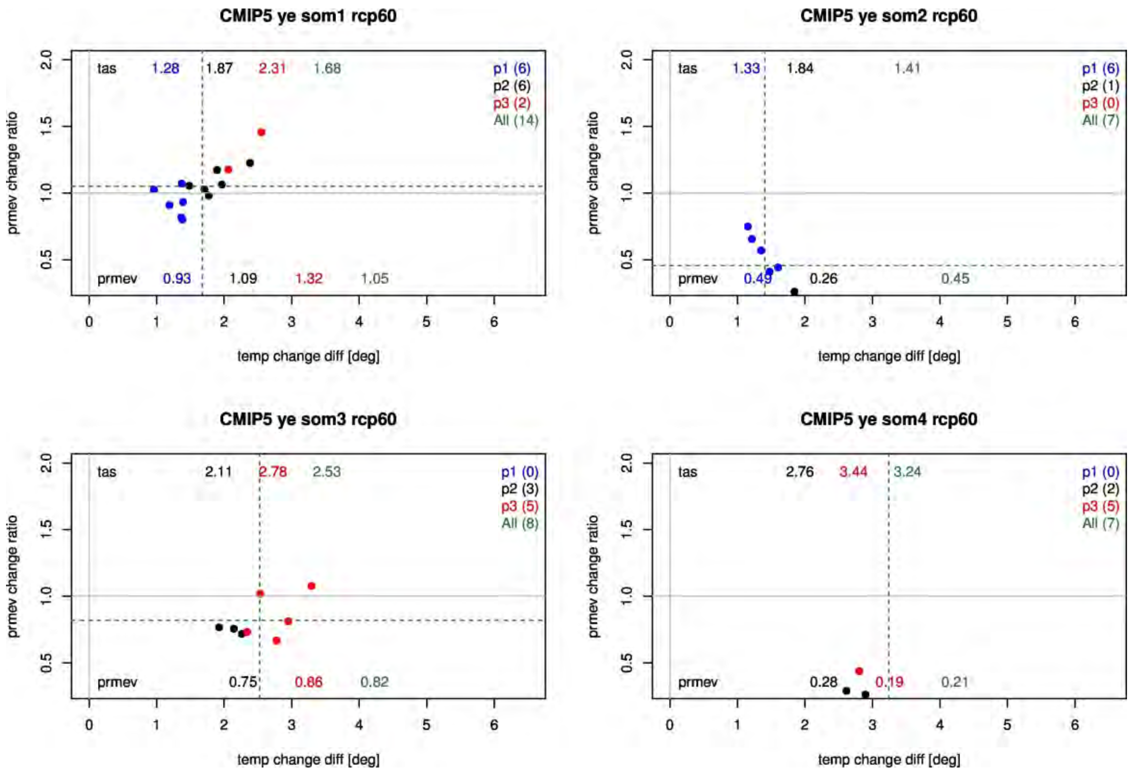


Figure WD14. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Waterberg Domain under RCP6.0; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 12 projections in CMIP5 for RCP6.0.

Table WD6a. Scenarios for the year over the Waterberg Domain under RCP6.0 based on Figure WD14 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
60	1→3	1.25ºC/0.95	2.00ºC/1.05	2.50ºC/0.90
40	2→4	1.25ºC/0.50	2.75ºC/0.30	3.50ºC/0.30

Summary: With the limited number of projections available these results need to be treated with caution. Visually there may be an overall weight towards reduced rainfall less evaporation, but this result is in part amplified by a small number of projections with substantial decreases in rainfall less evaporation.

RCP6.0; temperature vs rainfall less evaporation

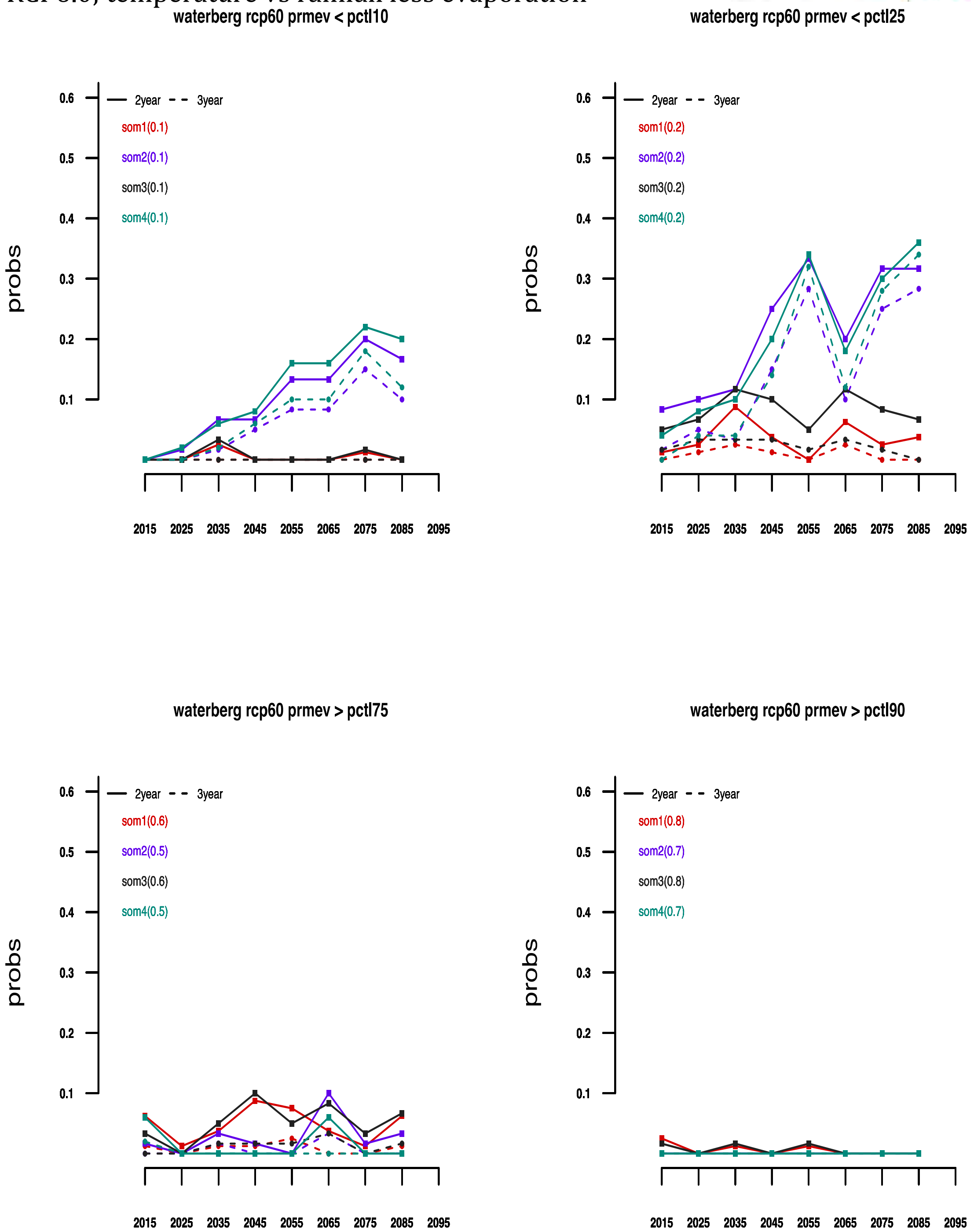


Figure WD118. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD14 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP8.5; temperature vs rainfall

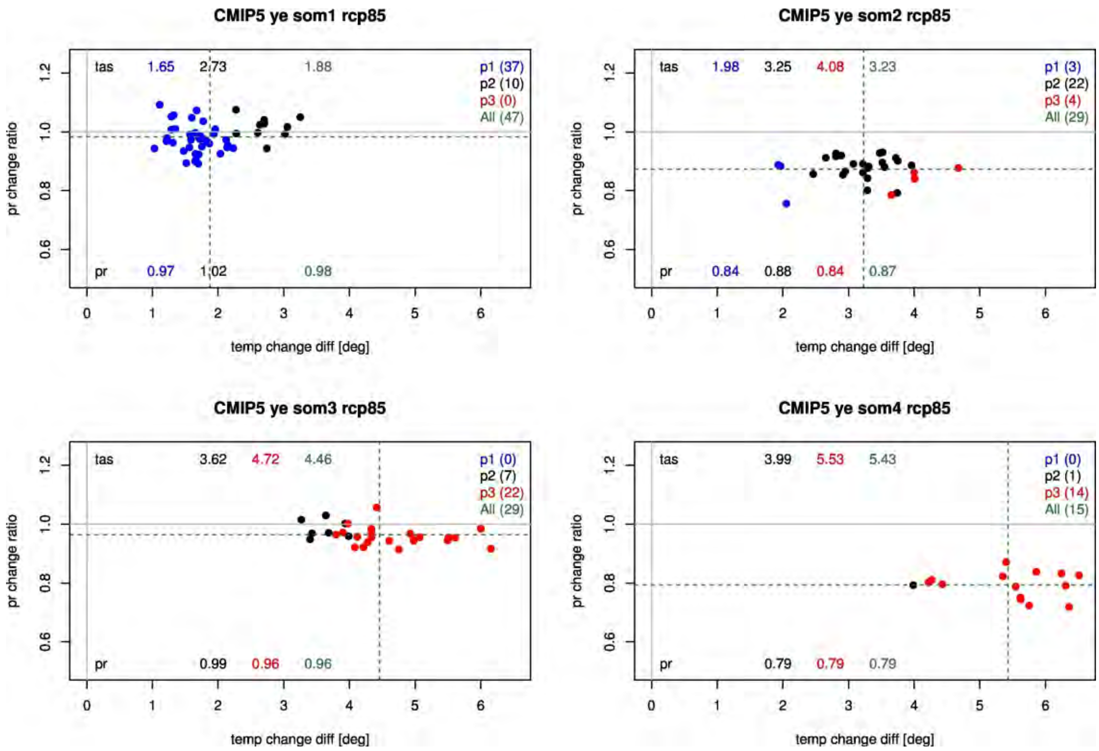


Figure WD16. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Waterberg Domain under RCP8.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 40 projections available in CMIP5 for RCP8.5.

Table WD7a. Scenarios for the year over the Waterberg Domain under RCP8.5 based on Figure WD16 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
60	1→2→4	1.75ºC/0.95	3.00ºC/0.90	5.50ºC/0.80
40	1→3	1.75ºC/0.95	3.00ºC/1.00	4.75ºC/0.95

Summary: Both scenarios ultimately lead to a drier climate, more quickly with the warmer scenario with higher likelihood.

RCP8.5; temperature vs rainfall

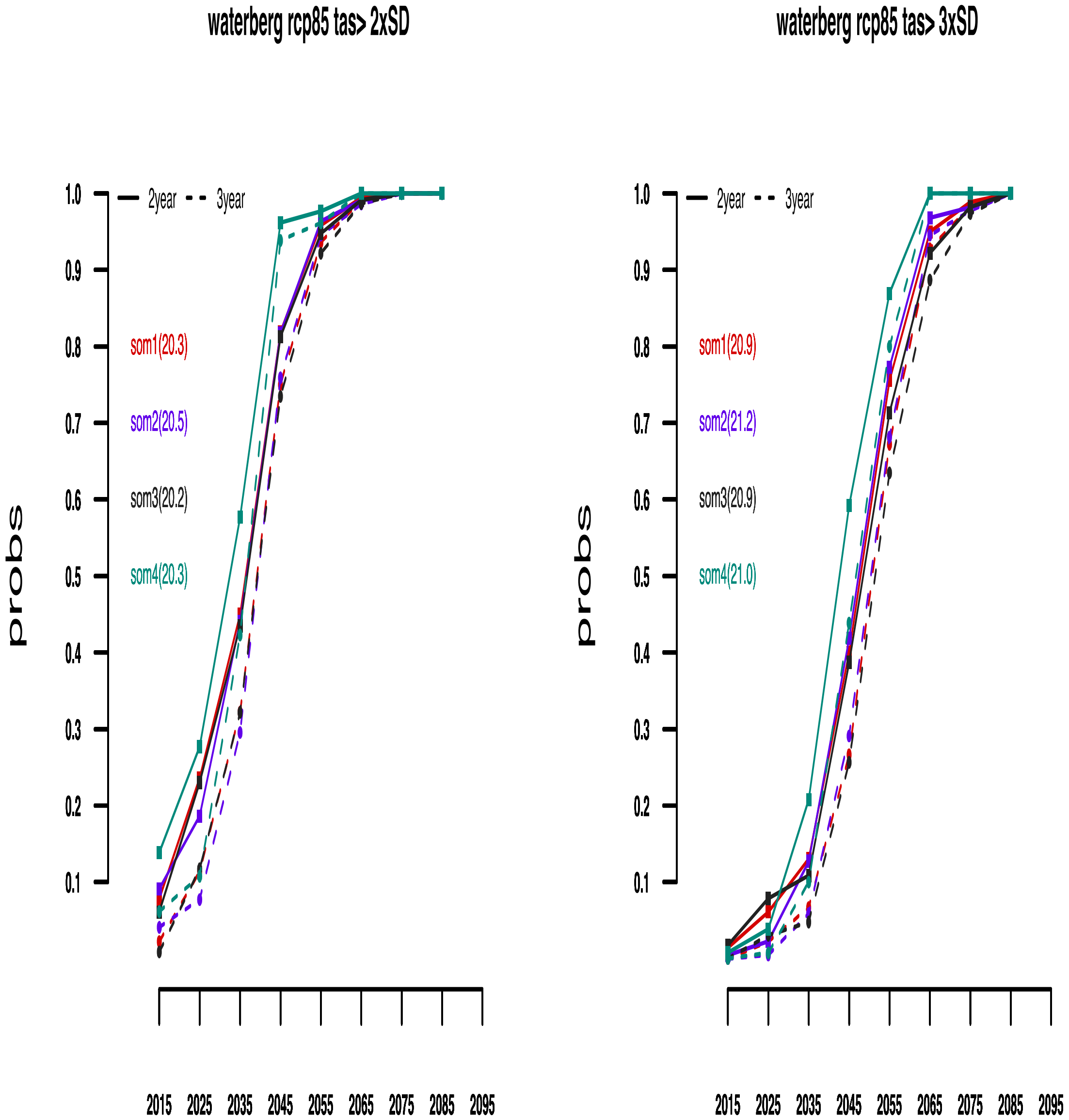


Figure WD17. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD16 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP8.5; temperature vs rainfall

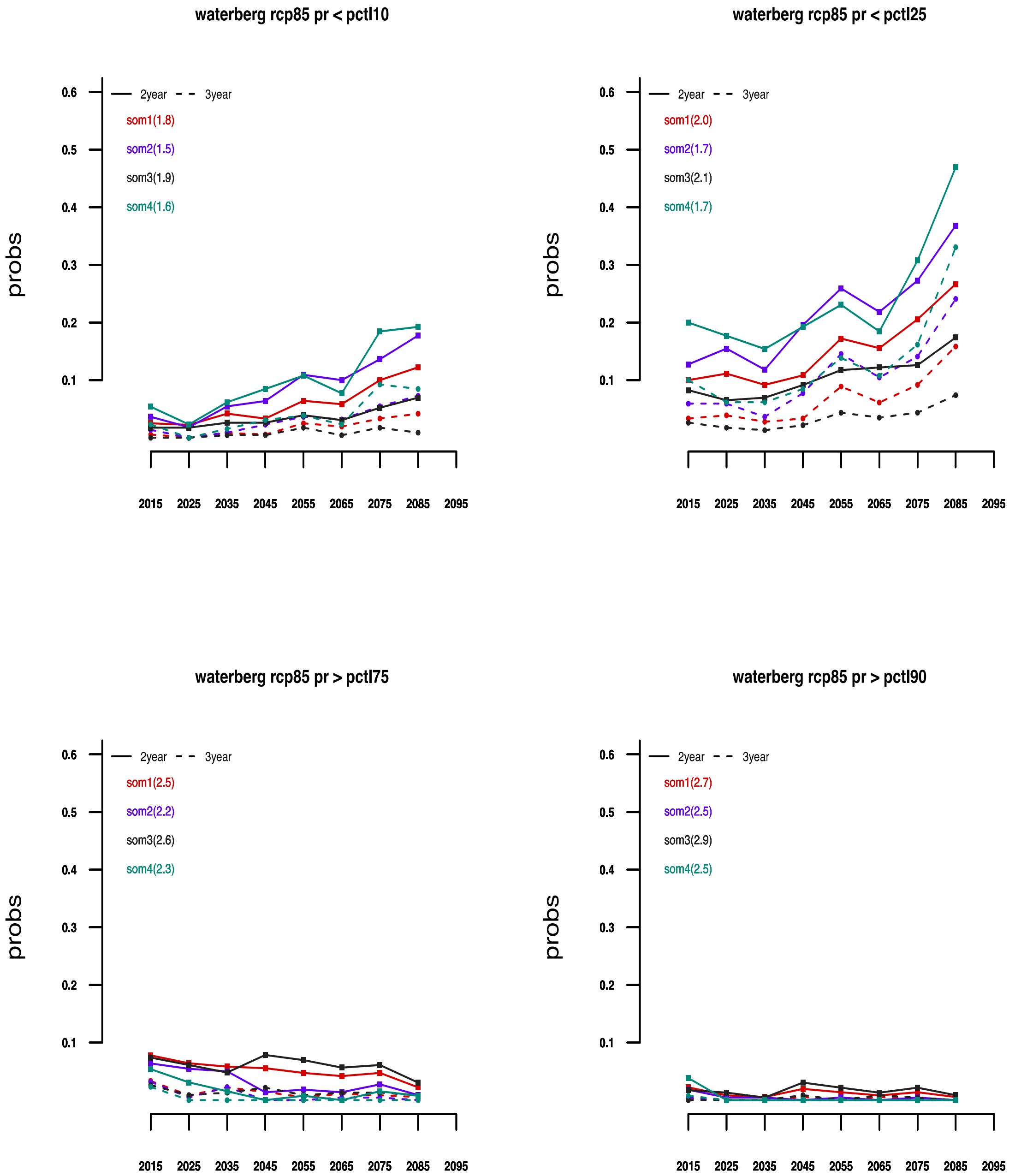


Figure WD18. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD16 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

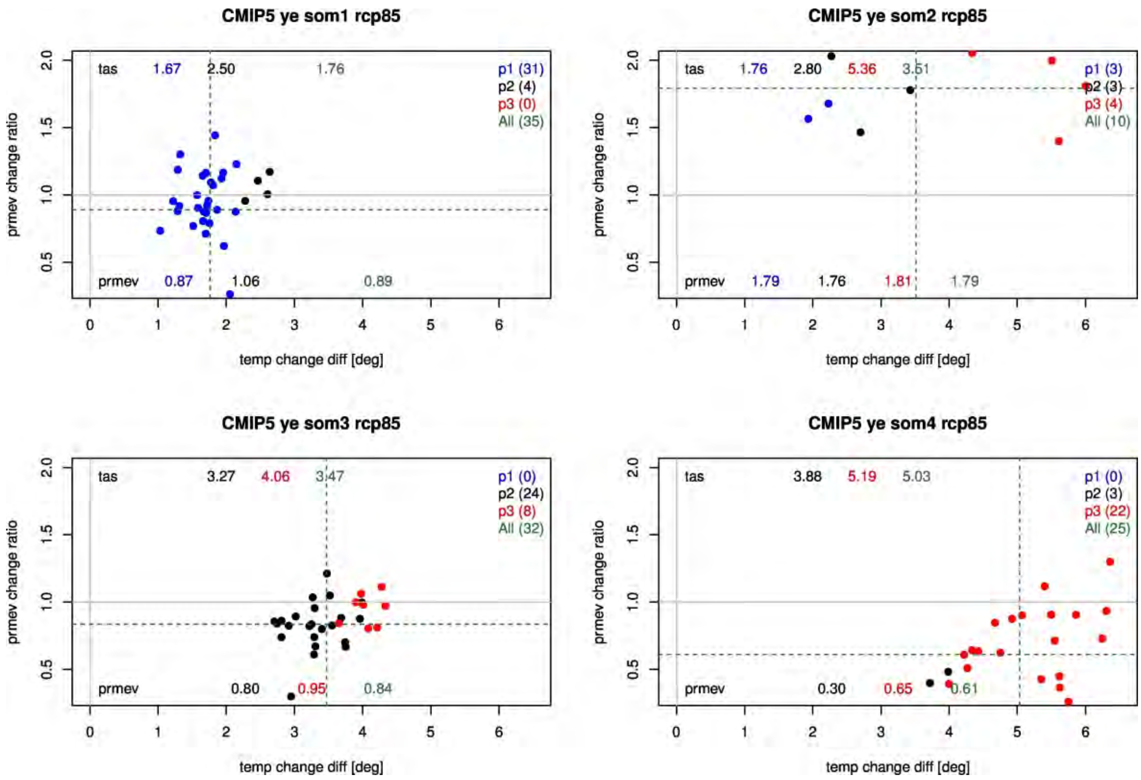


Figure WD19. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Waterberg Domain under RCP8.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 34 projections in CMIP5 for RCP8.5.

Table WD8a. Scenarios for the year over the Waterberg Domain under RCP8.5 based on Figure WD19 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
90	1→3→4	1.75ºC/0.85	3.25ºC/0.85	5.00ºC/0.70
10	1→2	1.75ºC/0.90	2.75ºC/1.50	5.25ºC/1.80

Summary: Despite the substantial number of projections available this analysis appears to separate into a predominately drier scenario together with a low-likelihood wetter scenario. Visually the likelihood of increased rainfall less evaporation perhaps seems to be higher than suggested in the scenarios above.

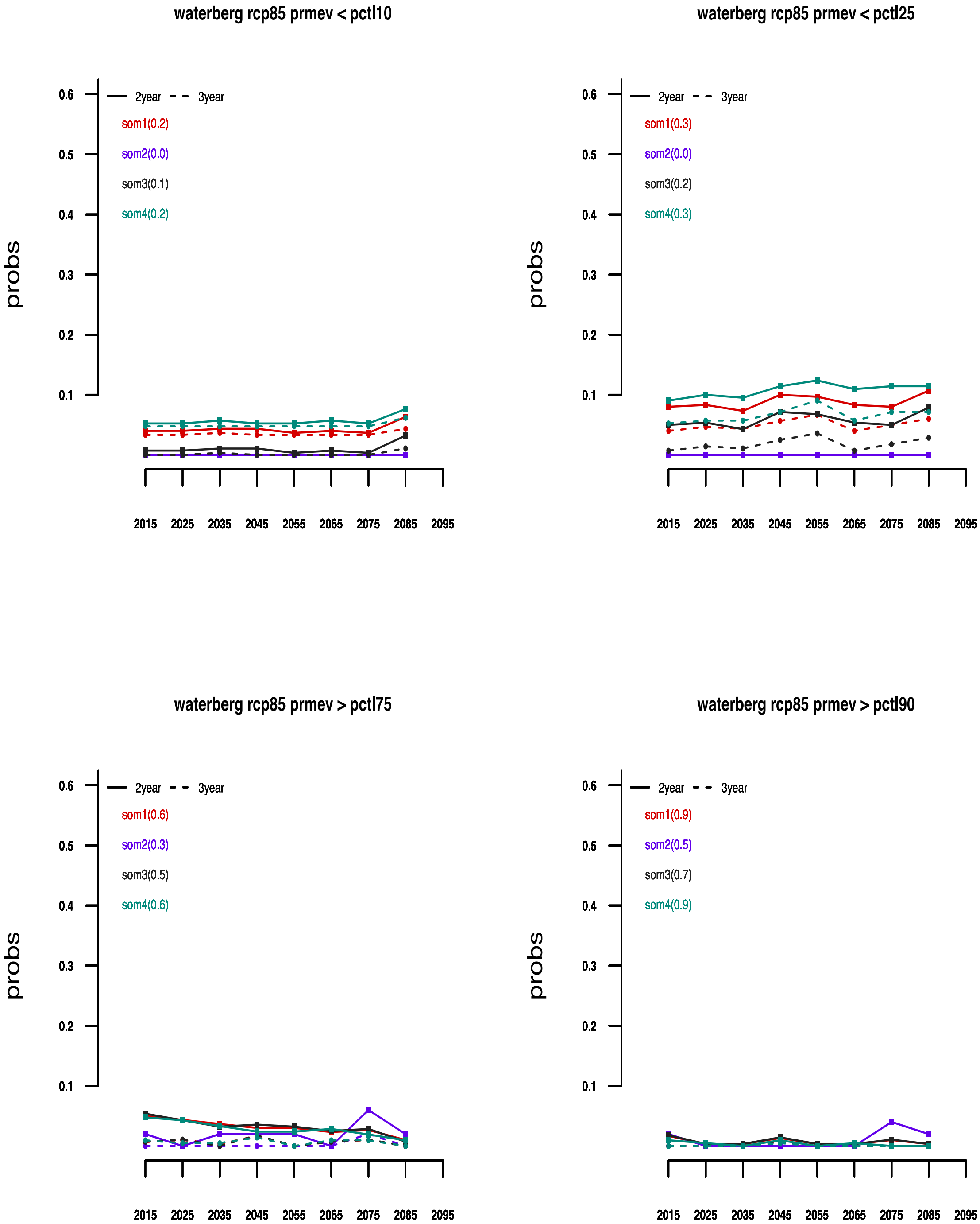


Figure WD20. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure WD19 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

Self-Organising Maps Results for the ZimBota Domain

Introduction. Results are presented below for the analyses through self-organising maps (soms) for the ZimBota Domain. Assessments of soms analyses for each RCP and temperature vs rainfall or temperature vs rainfall less evaporation are presented individually towards the end of this document; RCPs start at 2.6 and increase successively, temperature vs rainfall is presented before temperature vs rainfall less evaporation. Results from the soms are charted on each page followed by a table giving suggested scenarios from these particular results; a brief justification for the suggested scenarios is provided below each table.

Immediately following this introductory section is a collation of the results from the soms tables for easy reference. Below the collated table for each RCP is a further table giving, for each individual soms analysis, two suggested extreme scenarios, derived entirely subjectively. These extreme scenarios focus on changes to rainfall or to rainfall less evaporation as appropriate, and are an attempt to indicate possible scenarios representing greatest reasonable increases or decreases in rainfall or in rainfall less evaporation for that particular RCP. Note that had the focus been towards relatively high/low temperature increases different extreme scenarios would have been produced on at least some occasions. Thus the suggested extreme scenarios do not capture necessarily greatest and least changes in temperature projected for that RCP.

The number of projections for a given RCP, listed in the soms charts captions and repeated in the collation tables, may differ between the temperature against rainfall alone analyses and the temperature against rainfall less evaporation analyses for technical reasons.

Also provided following the tables of recommended scenarios for each RCP overall, and towards the end of this document for individual soms under each RCP, are results for the inter-annual variability (IAV) calculations. These illustrate future decadal probabilities that in successive two- and three-year periods:

- annual temperatures will exceed +2 and +3 standard deviations
- annual rainfall totals or rainfall less evaporation values will be below the 10th and 25th percentiles
- annual rainfall totals or rainfall less evaporation values will be above the 75th and 90th percentiles

relative to values across the base period of 1979-2005. Temperature probabilities have been presented only for the temperature vs rainfall soms as those for the temperature vs rainfall less evaporation soms are equivalent. Details of these charts are discussed further in the main document. Equivalent charts of IAV calculations for each RCP in total are provided immediately following the summary tables and before details of individual RCPs.

Summary of results.

Temperature against rainfall. As might be expected, temperatures in the RCP scenarios increase with emissions, a rise that is, in general, greater for the drier scenarios. Rainfall changes in both directions appear in all suggested scenarios for individual RCPs, whether that might be an increase, or at least little change from current conditions, or a decrease, but with mixed signals in terms of likelihoods. The exception is RCP8.5, for which the likelihood of a decrease is notably higher than that of an increase. Overall the balance of likelihoods appears to be towards future decreases in water availability, or at best a limited increase if any.

Temperatures in the recommended extreme scenarios increase in general with RCP; rainfall changes in these scenarios may move further away from 1.00 with increasing RCP, although the change is most noticeable with RCP8.5.

Likelihoods of annual temperatures exceeding two and three standard deviations calculated across the base period of 1979-2005 increase, naturally, with RCP (see Figure ZA), but vary also according to individual soms (see diagrams in the sections for the individual RCPs). Under RCP8.5 successive two and three year periods are almost certain by the 2070's for two standard deviations and by the 2060's for three standard deviations. By contrast, under RCP2.6 none of the soms produces 100% probabilities for two standard deviations whether over two or over three year periods, whereas for three standard deviations probabilities peak for just one som at around 50%. For both RCP4.5 and RCP6.0 100% probabilities are reached only by the end of the century, and only for two standard deviations.

Likelihoods of both two- and three-year annual rainfall totals outside tend to increase in time and with RCP for the 10th and 25th percentiles, and to decrease for the 75th and 90th percentiles (see Figure ZB). Similar increasing/decreasing trends of these likelihoods in time are in general apparent for all individual RCPs also, but there is also distinct differences in likelihoods for individual soms (see diagrams in the sections for the individual RCPs).

Temperature against rainfall less evaporation. The picture is a little more complex for rainfall less evaporation. For RCP2.6, RCP4.5 and RCP8.5 there is a distinct bias towards future drier conditions, with an estimate of an 85% likelihood of drier conditions in RCP4.5. For RCP6.0 (note: with the lowest projections population) there is a slightly higher likelihood of future wetter conditions.

Temperatures in the suggested extreme scenarios increase in general with RCP; there might be a steady movement away from 1.00 for the rainfall less evaporation values with increasing RCP in these scenarios, reaching about ±50% for RCP8.5.

Likelihoods of annual rainfall less evaporation amounts outside the 10th and 90th percentiles over 2 and 3 years do not change substantially, in general being below 10% but are perhaps increased above this towards the end of the century for the higher RCPs (see Figure ZC). There may be an overall tendency for all likelihoods, whether for decreased or increased rainfall less evaporation, to increase with RCP, suggesting broader distributions of amounts under the higher RCPs. There are increasing/decreasing respectively likelihoods of 2/3 year values outside the 25th and 75th percentiles as the century proceeds, especially for RCP6.0 and RCP8.5 (see Figures in individual sections), with perhaps a slight weighting towards greater likelihoods for below the 25th percentile than for above the 75th (i.e. a skewing towards drier conditions). For many soms likelihoods in either direction remain below 10% throughout, but for some they may reach 25%.

Conclusions. In section 3 of the main report it was noted that ZimBota sits at a location approximately where the ensemble means paint a consistent picture of reduced rainfall but equivalently are unclear about the direction of any rainfall less evaporation changes, both increases and decreases being suggested. The soms analyses, for rainfall and rainfall less evaporation, tend to suggest future drier conditions overall, but the signal is somewhat mixed.

Across RCP2.6, RCP4.5 and RCP6.0 there is some consistency between suggested scenarios in terms of adjustments in rainfall and in rainfall less evaporation notwithstanding small increases in temperature with rising emissions. As found in most other areas for which the soms technique has been applied RCP8.5 stands out somewhat, both in terms of higher temperature increases as well as in adjustments to rainfall/rainfall less evaporation. Hence the recommendations below are weighted away from RCP8.5. The overall recommendations based on the temperature against rainfall analyses are for a slightly higher likelihood of little change in rainfall as against a steady decline. The analyses using rainfall less evaporation, on the other hand, indicate rather likely likelihoods of future decreases in water availability. These differences in likelihoods between the two sets of analyses are consistent as far as can be detected and take into consideration increased evaporation as temperatures rise.

If there is a requirement to examine projected changes under RCP8.5 then use the recommended and extreme scenarios repeated from the appropriate collated tables below.

The IAV calculations indicate steady increases in time in likelihoods of extended 2- and 3-year spells of temperatures above historical annual 2 and 3 standard deviations, greater with higher RCPs and reaching 100% in many cases towards the end of the century. Both for rainfall and for rainfall less evaporation likelihoods of extended 2- and 3-years spells below and above historical annual 10th and 90th percentiles do not change significantly in time, but those for the 25th and 75th percentiles do (although not for all soms), especially for RCP6.0 and RCP8.5, suggesting an increase in spread of annual values with possible slight bias towards drier conditions.

Recommended Scenarios for the ZimBota Domain based on RCP2.6, RCP4.5 and RCP6.0

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
60	1.25ºC/1.00	1.75ºC/1.05	2.00ºC/1.00
40	1.50ºC/0.95	2.00ºC/0.90	2.75ºC/0.85

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall changes)

	2040	2065	2080
Increased	1.00ºC/1.10	1.75ºC/1.10	2.00ºC/1.10
Decreased	1.50ºC/0.90	2.00ºC/0.85	3.00ºC/0.85

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
65	1.50ºC/0.75	2.00ºC/0.80	2.50ºC/0.80
35	1.25ºC/1.05	1.50ºC/1.25	1.50ºC/1.30

Extreme scenarios based on temperature against rainfall less evaporation analyses (focussed primarily on rainfall less evaporation changes)

	2040	2065	2080
Increased	1.00ºC/1.30	1.75ºC/1.30	2.25ºC/1.40
Decreased	1.25ºC/0.65	2.25ºC/0.65	3.00ºC/0.55

Recommended Scenarios for the ZimBota Domain based on RCP8.5

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
55	1.50ºC/0.95	3.00ºC/0.90	5.00ºC/0.75
45	1.50ºC/1.00	3.00ºC/1.00	4.50ºC/0.95

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall changes)

	2040	2065	2080
Increased	1.25ºC/1.10	2.25ºC/1.10	4.50ºC/1.10
Decreased	1.50ºC/0.85	3.00ºC/0.80	5.25ºC/0.70

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
75	1.50ºC/0.90	3.25ºC/0.80	4.75ºC/0.80
25	1.50ºC/1.00	2.75ºC/1.60	5.00ºC/2.00

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall less evaporation changes)

	2040	2065	2080
Increased	1.25ºC/1.50	2.75ºC/1.65	5.25ºC/1.50
Decreased	1.50ºC/0.70	3.25ºC/0.50	5.25ºC/0.50

Scenarios from each RCP for the ZimBota Domain based on analyses of temperature against rainfall to the left and on analyses of temperature against rainfall less evaporation to the right; in the summaries following each table TR refers to the temperature/rainfall table to the left and TRLE to the temperature/rainfall less evaporation table to the right. Following the RCP header are the numbers of projections available to produce TR and TRLE respectively. Note that the soms numbers in the second columns of each individual table are arbitrary and should not be used to inter-compare TR and TRLE.

RCP2.6 – 20 and 18 projections

	%		2040	2065	2080		%		2040	2065	2080
1	35	1	1.00ºC/0.95	1.00ºC/1.00	0.90ºC/1.00		45	2	1.25ºC/0.80	1.25ºC/0.80	1.50ºC/0.90
2	35	2	1.50ºC/0.95	1.50ºC/0.95	1.50ºC/0.90		35	1	1.00ºC/1.10	1.00ºC/1.10	1.00ºC/1.00
3	15	3	1.75ºC/0.90	2.25ºC/0.85	2.25ºC/0.90		15	3	1.75ºC/0.80	2.25ºC/0.80	2.25ºC/0.80
4	15	4	0.75ºC/1.10	1.00ºC/1.10	1.00ºC/1.15		5	4	1.00ºC/1.30	1.25ºC/1.45	1.25ºC/2.00

Summary: According to the TRLE scenarios a decrease in water availability is the most likely future in this Domain. From TR, on the other hand, there is a rough balance between increased and decreased rainfall likelihoods at levels that might not appear consistent with some of the TRLE results: the differences are almost certainly down to proportionately increased simulations of evaporation as contrasted to rainfall.

Suggested extreme scenarios for RCP2.6 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.00ºC/1.10	1.00ºC/1.10	1.00ºC/1.10		1.00ºC/1.25	1.25ºC/1.10	1.75ºC/1.20
Decreased	1.50ºC/0.90	1.75ºC/0.90	2.00ºC/0.90		1.50ºC/0.75	2.00ºC/0.75	2.00ºC/0.70

RCP4.5 – 38 and 33 projections

	%		2040	2065	2080		%		2040	2065	2080
1	50	1→3	1.25ºC/1.00	1.75ºC/1.00	2.00ºC/0.95		45	2	1.75ºC/0.75	2.00ºC/0.85	2.00ºC/0.90
2	30	1→2	1.25ºC/0.95	2.25ºC/0.90	2.50ºC/0.85		40	1→4	1.50ºC/1.05	2.25ºC/0.95	3.00ºC/0.85
3	20	1→4	1.25ºC/1.00	1.75ºC/1.05	2.75ºC/1.00		15	1→3	1.25ºC/1.05	2.00ºC/1.30	2.50ºC/1.80

Summary: While in TR the higher likelihood overall is for little change in rainfall the weight in TRLE is distinctly towards reduced rainfall less evaporation. As for RCP2.6 the models appear to be simulating higher-likelihood increased evaporation resulting in overall reductions in water availability.

Suggested extreme scenarios for RCP4.5 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.25ºC/1.10	1.50ºC/1.10	2.50ºC/1.10		1.00ºC/1.40	2.00ºC/1.40	2.75ºC/1.60
Decreased	1.00ºC/0.90	2.00ºC/0.85	2.75ºC/0.85		1.25ºC/0.60	2.50ºC/0.60	3.00ºC/0.60

RCP6.0 – 15 and 12 projections

	%		2040	2065	2080		%		2040	2065	2080
1	60	1→3	1.00ºC/1.00	1.75ºC/1.05	2.75ºC/1.00		60	1→3	1.25ºC/1.00	2.00ºC/1.25	2.50ºC/1.25
2	40	2→4	1.50ºC/0.90	2.50ºC/0.90	3.25ºC/0.85		40	2→4	1.25ºC/0.55	2.50ºC/0.55	3.25ºC/0.50

Summary: One of the more notable aspects of this to be taken into consideration is the relatively small number of projections available for TRLE, which gives reduced confidence in these results. Nevertheless both analyses split with slightly higher likelihoods for maintaining or increasing future rainfall and rainfall less evaporation and lesser likelihoods for substantial reductions in these.

Suggested extreme scenarios for RCP6.0 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.00ºC/1.05	2.00ºC/1.10	2.00ºC/1.05		1.00ºC/1.25	1.75ºC/1.25	2.50ºC/1.25
Decreased	1.25ºC/0.85	2.25ºC/0.85	3.25ºC/0.85		1.25ºC/0.60	2.50ºC/0.60	3.25ºC/0.50

RCP8.5 – 40 and 35 projections

	%		2040	2065	2080		%		2040	2065	2080
1	55	1→2→4	1.50ºC/0.95	3.00ºC/0.90	5.00ºC/0.75		75	1→3→4	1.50ºC/0.90	3.25ºC/0.80	4.75ºC/0.80
2	45	1→3	1.50ºC/1.00	3.00ºC/1.00	4.50ºC/0.95		25	1→2→4	1.50ºC/1.00	2.75ºC/1.60	5.00ºC/2.00

Summary: undoubtedly the weight of these scenarios is for reductions in rainfall and in rainfall less evaporation, later if not sooner. A small number of the TRLE simulations suggest high increases in rainfall less evaporation, but there must be a suspicion that this results in part from relatively small differences in the base period.

Suggested extreme scenarios for RCP8.5 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.25ºC/1.10	2.25ºC/1.10	4.50ºC/1.10		1.25ºC/1.50	2.75ºC/1.65	5.25ºC/1.50
Decreased	1.50ºC/0.85	3.00ºC/0.80	5.25ºC/0.70		1.50ºC/0.70	3.25ºC/0.50	5.25ºC/0.50

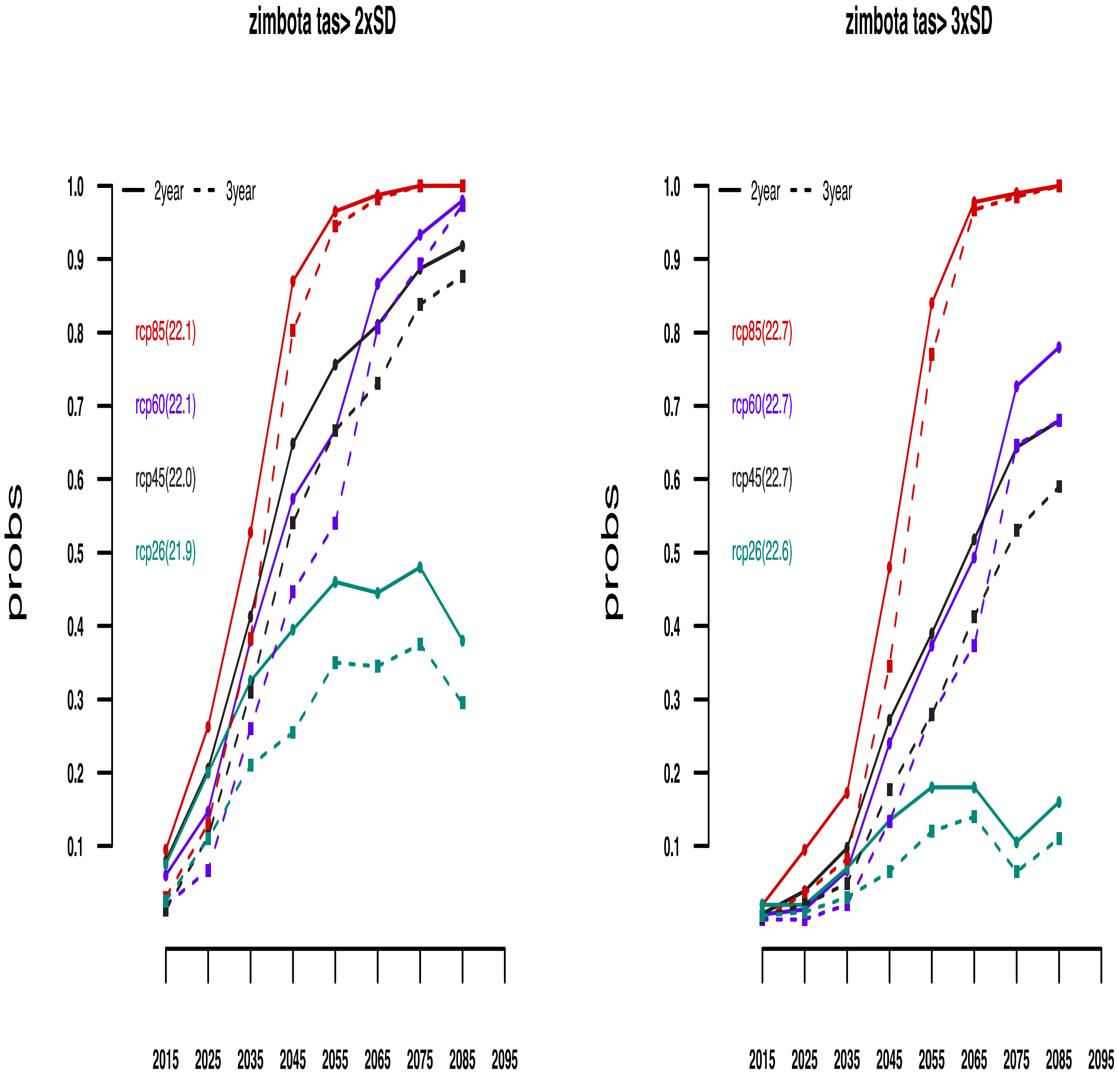


Figure ZA. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes.

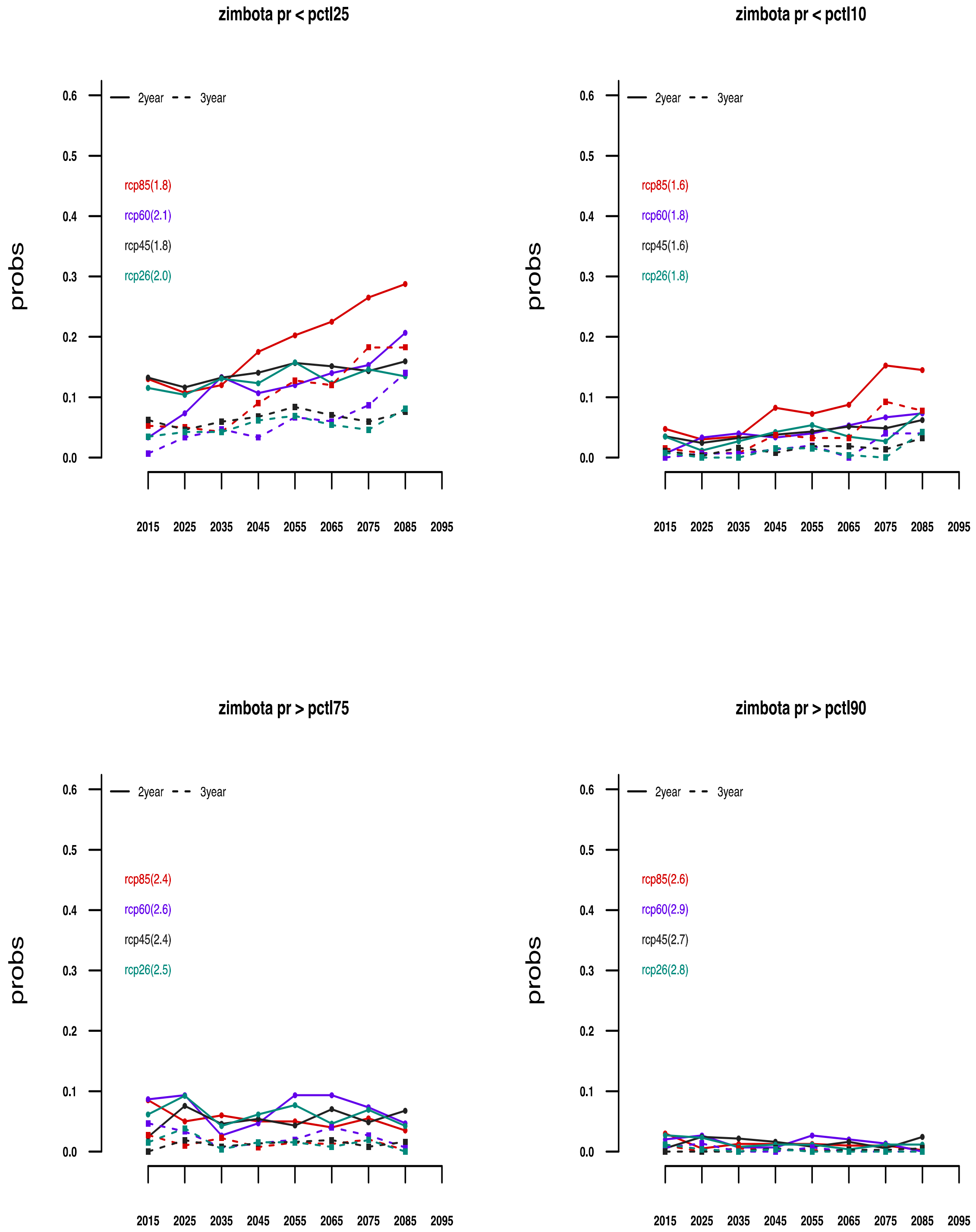


Figure ZB. Decadal probabilities that future annual rainfall totals will be below the 25th percentile (top left) or the 10th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the RCP numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

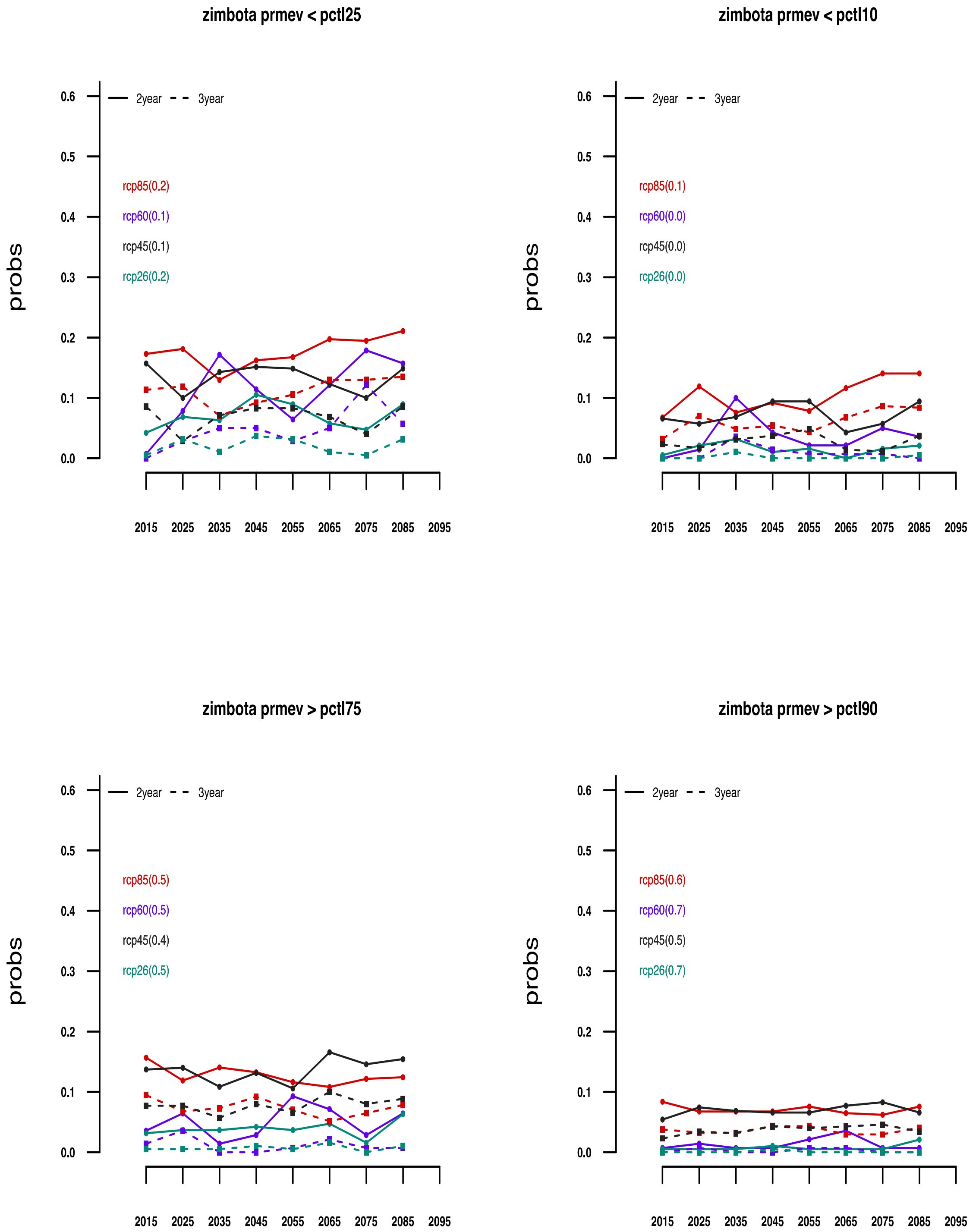


Figure ZC. Decadal probabilities that future annual rainfall less evaporation totals will be below the 25th percentile (top left) or the 10th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the RCP numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP2.6; temperature vs rainfall

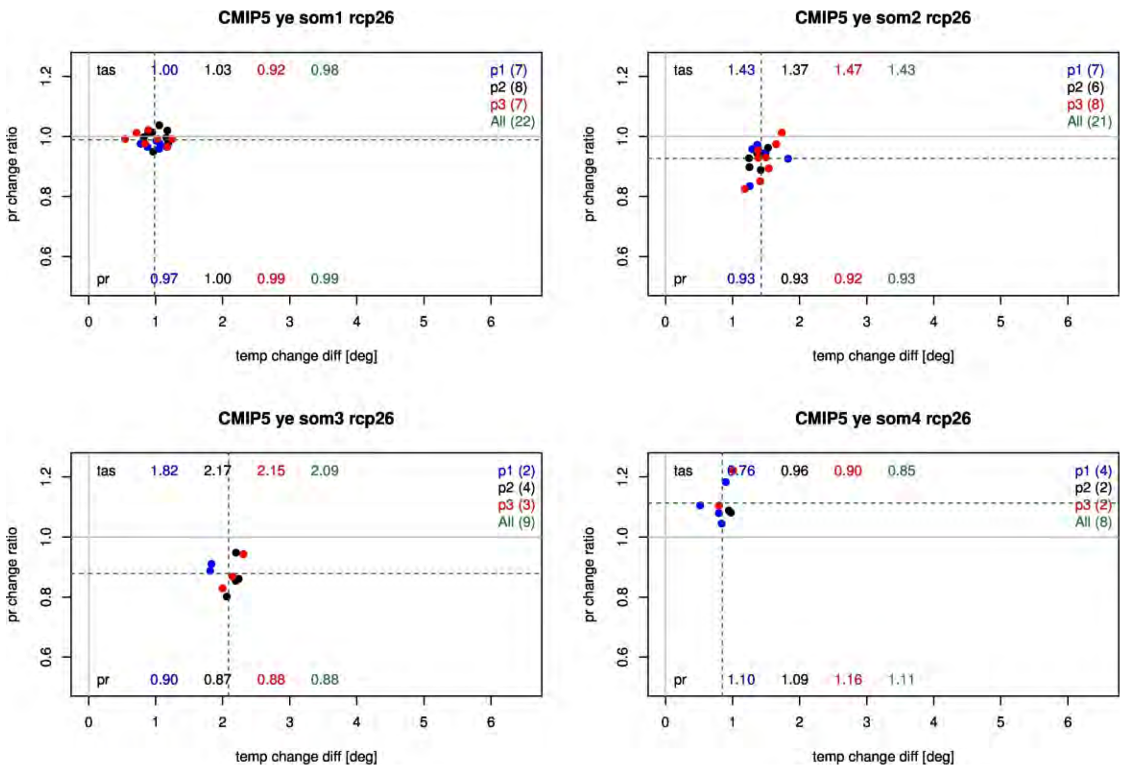


Figure ZD19. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the ZimBota Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 20 projections available in CMIP5 for RCP2.6.

Table ZD1a. Scenarios for the year over the ZimBota Domain under RCP2.6 based on Figure ZD1 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
35	1	1.00ºC/0.95	1.00ºC/1.00	0.90ºC/1.00
35	2	1.50ºC/0.95	1.50ºC/0.95	1.50ºC/0.90
15	3	1.75ºC/0.90	2.25ºC/0.85	2.25ºC/0.90
15	4	0.75ºC/1.10	1.00ºC/1.10	1.00ºC/1.15

Summary: Each som appears to form an individual pathway, with limited differences in likelihoods across all four. Overall there is perhaps a weight towards decreased (soms 2 and 3) and against increased rainfall or little change (soms 1 and 4). Temperature increases are higher for the drier scenarios.

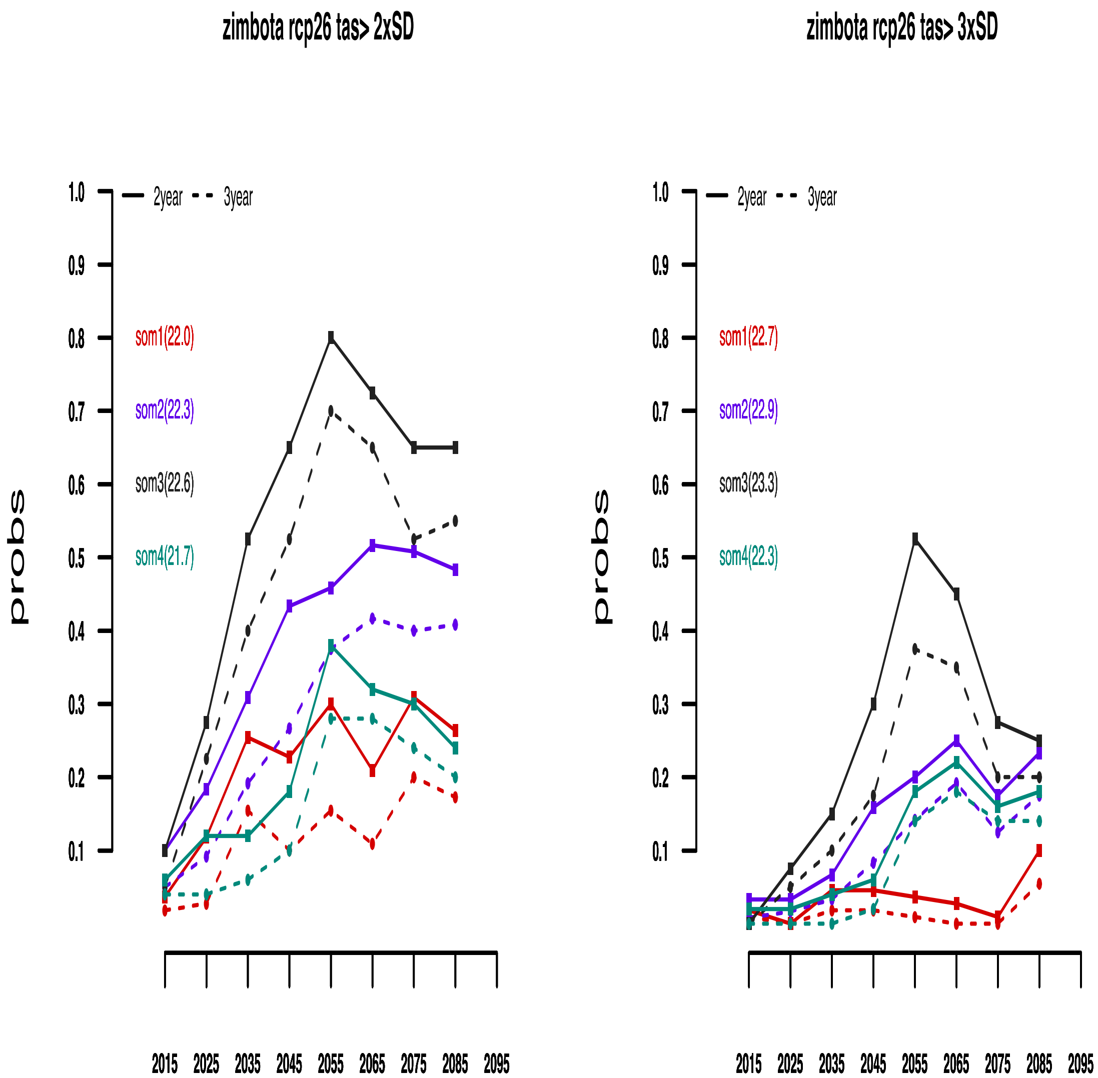


Figure ZD20. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD1 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP2.6; temperature vs rainfall

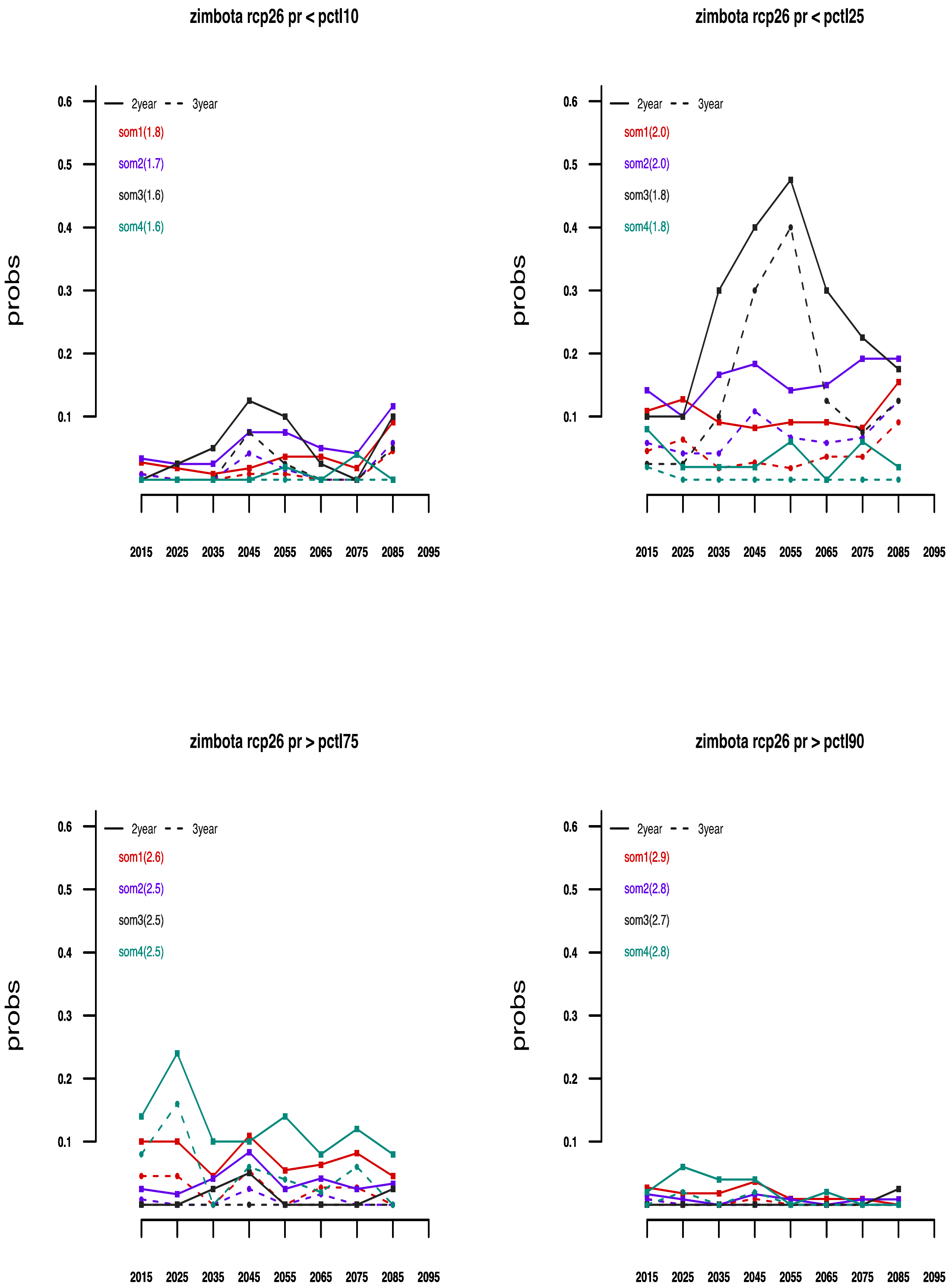


Figure ZD21. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD1 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

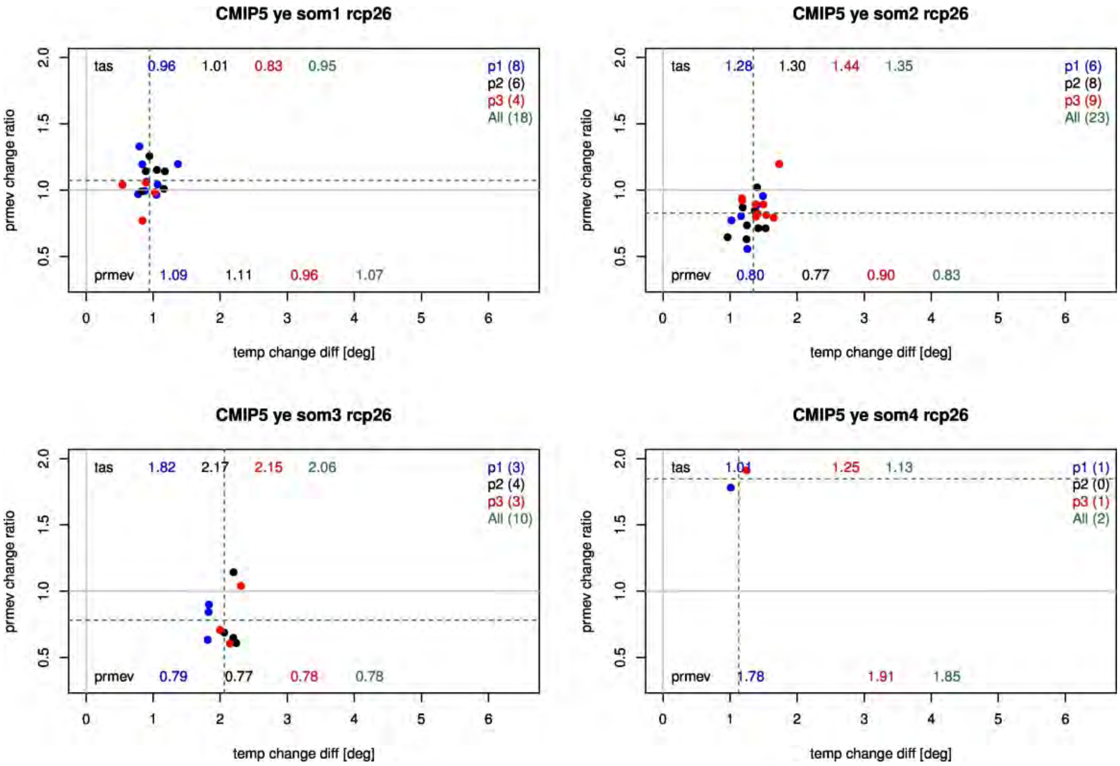


Figure ZD4. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the ZimBota Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 18 projections available in CMIP5 for RCP2.6.

Table ZD2a. Scenarios for the year over the ZimBota Domain under RCP2.6 based on Figure ZD4 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
45	2	1.25ºC/0.80	1.25ºC/0.80	1.50ºC/0.90
35	1	1.00ºC/1.10	1.00ºC/1.10	1.00ºC/1.00
15	3	1.75ºC/0.80	2.25ºC/0.80	2.25ºC/0.80
5	4	1.00ºC/1.30	1.25ºC/1.45	1.25ºC/2.00

Summary: Four separate scenarios, but the two with lowest likelihoods may be relatively high rainfall less evaporation change outliers because of small values during the base period of 1979-2005; som 4 in particular might be ignored. Of the two higher-likelihood scenarios, the higher marginally suggests a decrease in rainfall less evaporation, the second little change or perhaps an increase.

RCP2.6; temperature vs rainfall less evaporation

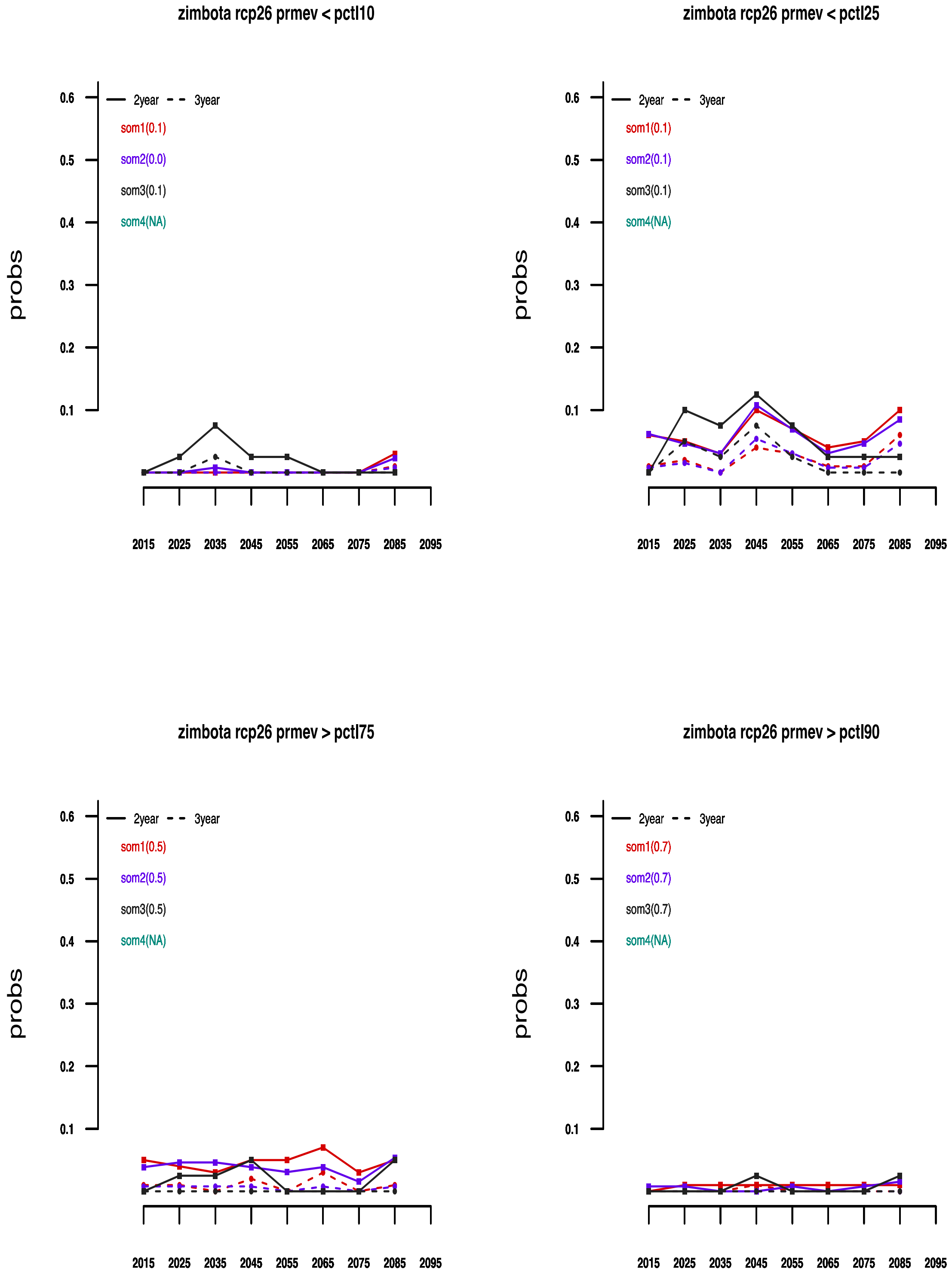


Figure ZD22. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD3 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall

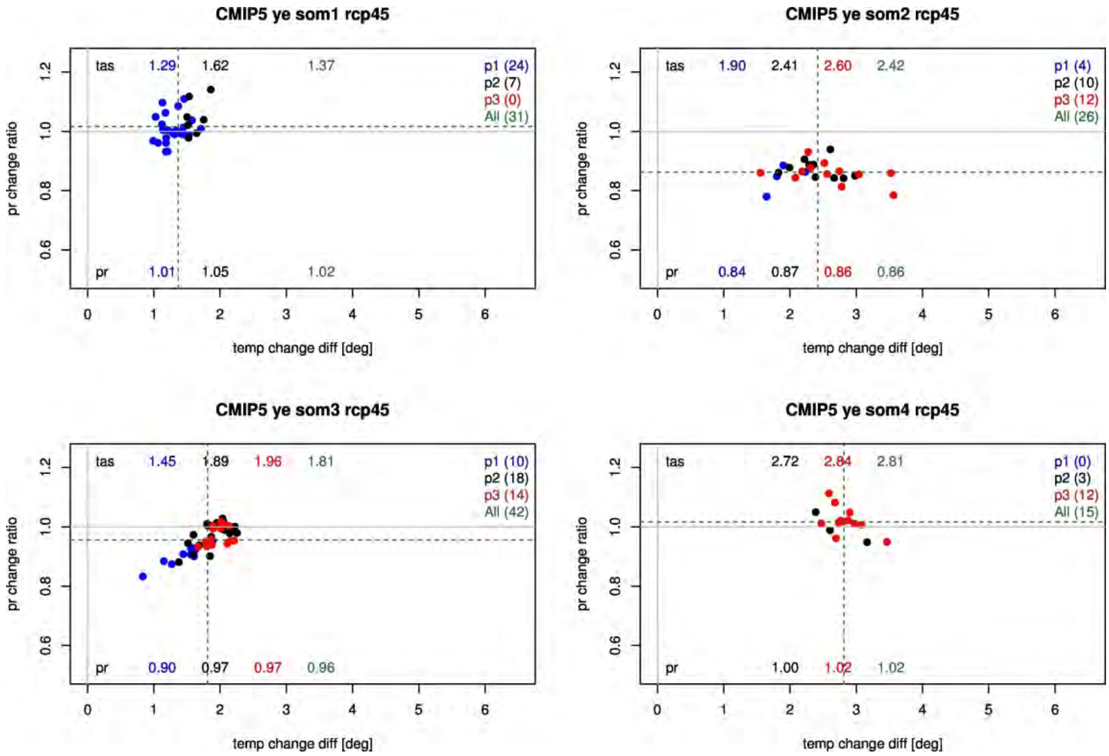


Figure ZD6. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the ZimBota Domain under RCP4.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 38 projections available in CMIP5 for RCP4.5.

Table ZD3a. Scenarios for the year over the ZimBota Domain under RCP4.5 based on Figure ZD6 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
50	1→3	1.25ºC/1.00	1.75ºC/1.00	2.00ºC/0.95
30	1→2	1.25ºC/0.95	2.25ºC/0.90	2.50ºC/0.85
20	1→4	1.25ºC/1.00	1.75ºC/1.05	2.75ºC/1.00

Summary: An alternate interpretation might be 1→4 and 3→2, but with most p1 points in som 1 the suggested interpretation is for three pathways from that som. There appears to be a higher likelihood of reduced rainfall, particularly towards p3 (soms 1→2 and 1→3), but equally there is a reasonable likelihood of limited changes in rainfall (soms 1→3 and 1→4).

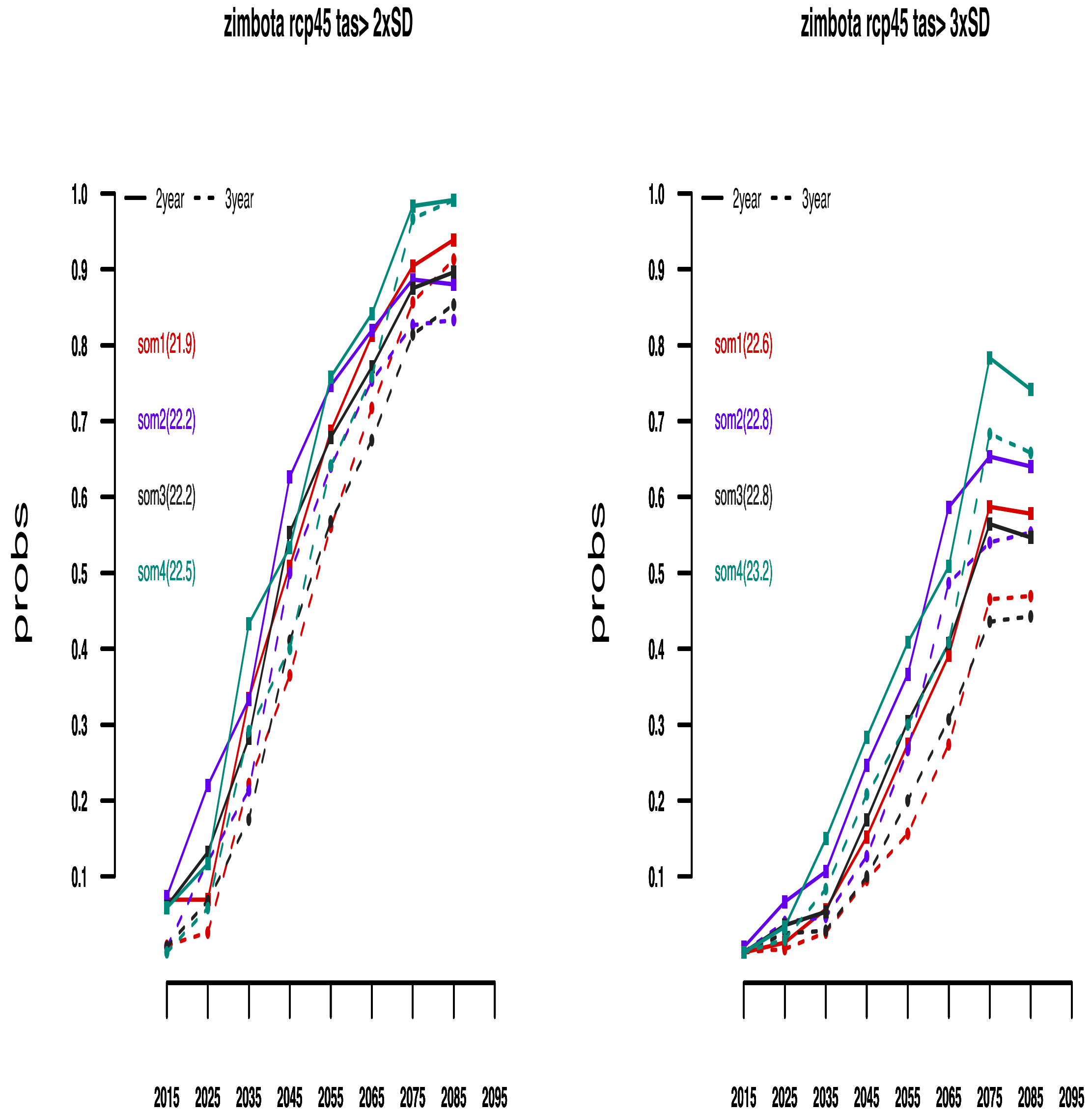


Figure ZD7. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD6 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall

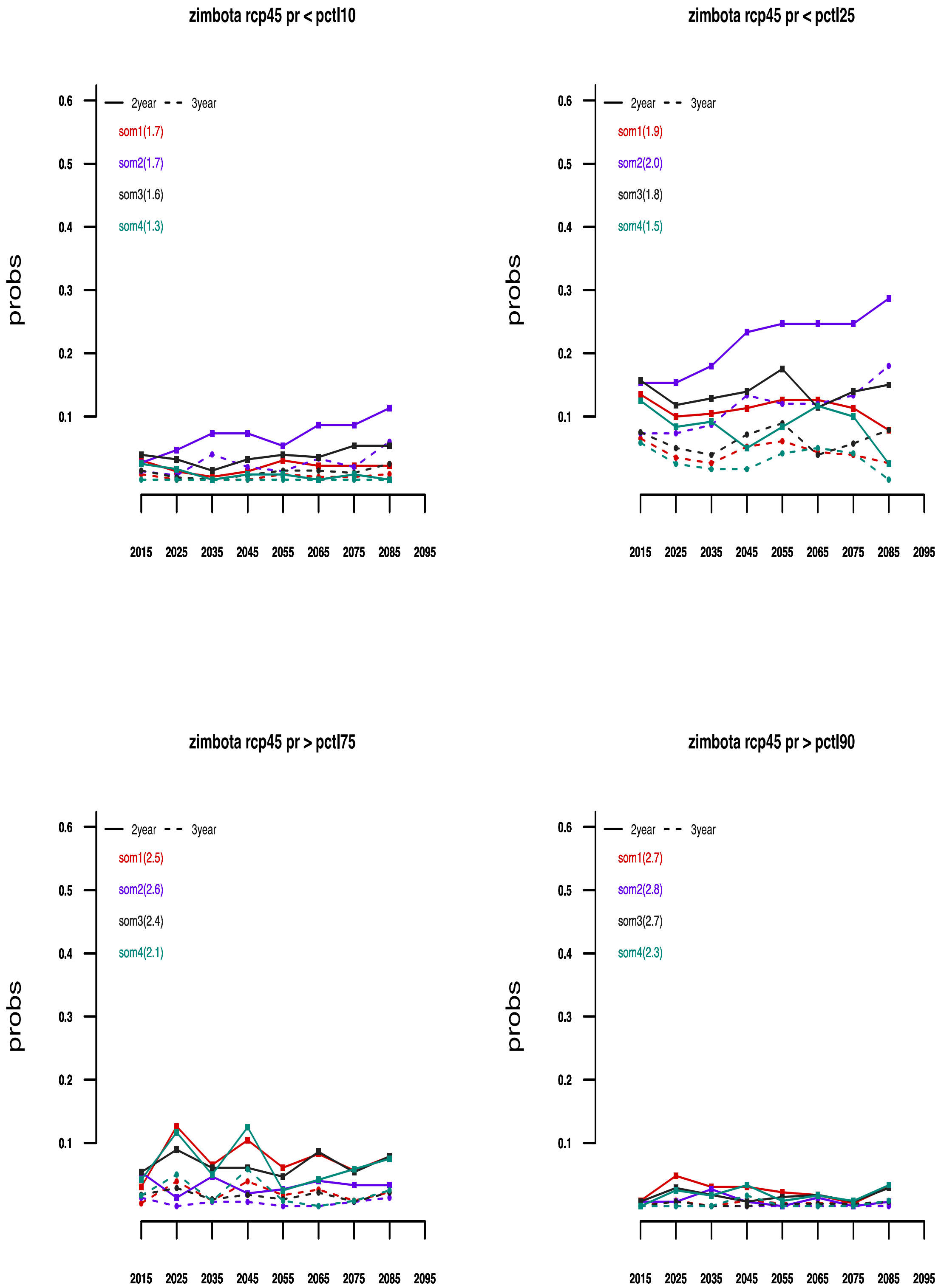


Figure ZD8. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD6 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall

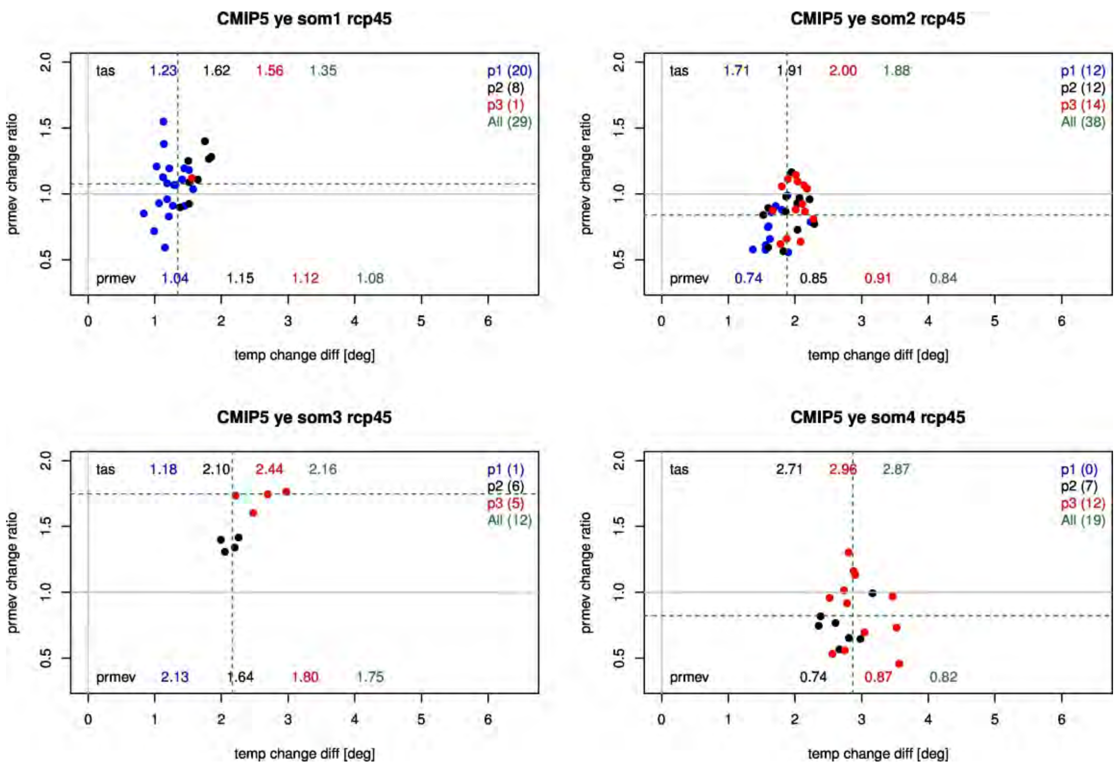


Figure ZD9. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the ZimBota Domain under RCP4.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 33 projections available in CMIP5 for RCP4.5.

Table ZD4a. Scenarios for the year over the ZimBota Domain under RCP4.5 based on Figure ZD9 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
45	2	1.75ºC/0.75	2.00ºC/0.85	2.00ºC/0.90
40	1→4	1.50ºC/1.05	2.25ºC/0.95	3.00ºC/0.85
15	1→3	1.25ºC/1.05	2.00ºC/1.30	2.50ºC/1.80

Summary: The interpretation suggested is that there is one pathway lying entirely in som2 while two pathways begin in som1 where the majority of remaining p1 points lie. The overall picture is one of a decrease in water availability, with only the low-likelihood 1→3 scenario suggesting an increase.

RCP4.5; temperature vs rainfall

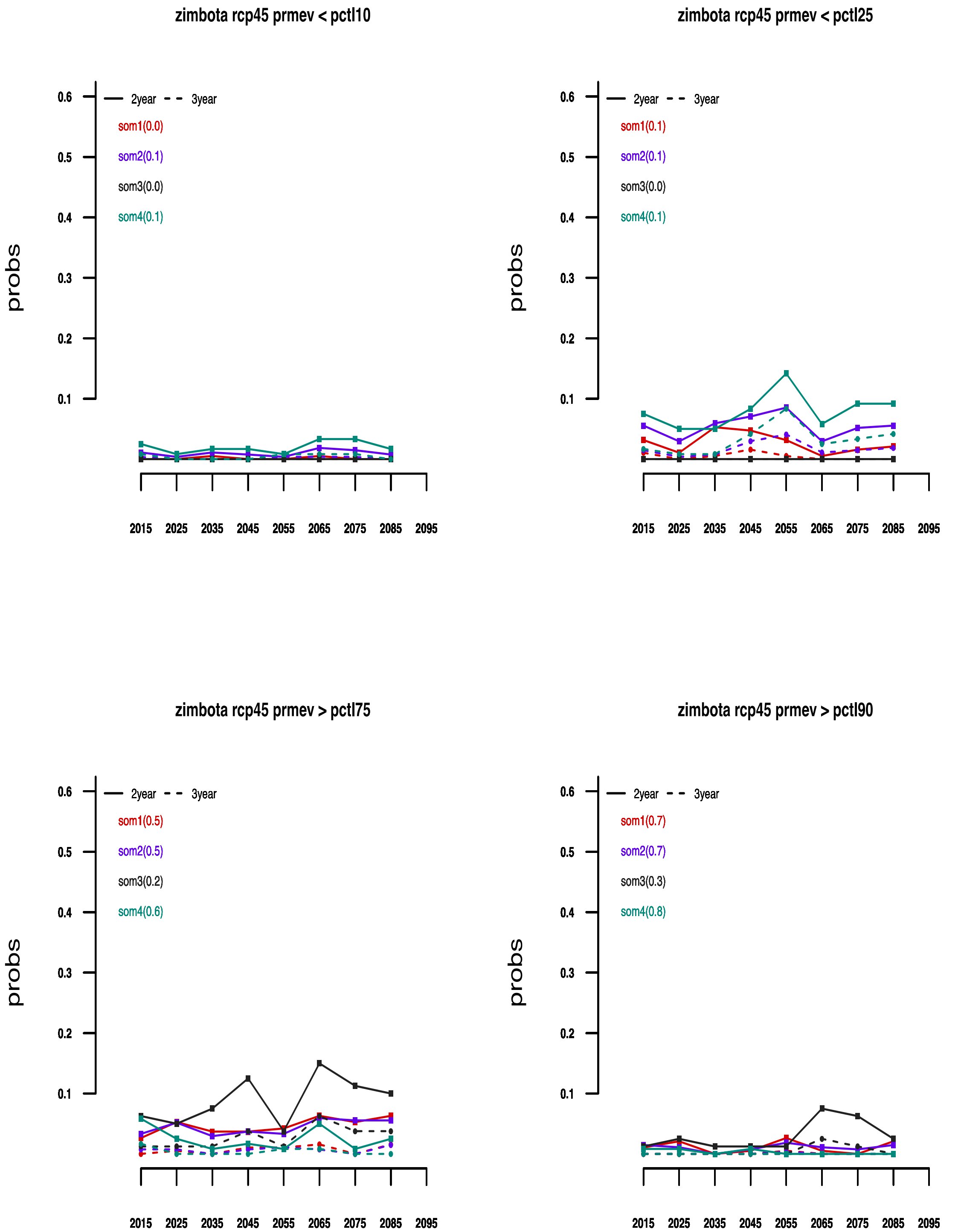


Figure ZD10. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD9 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

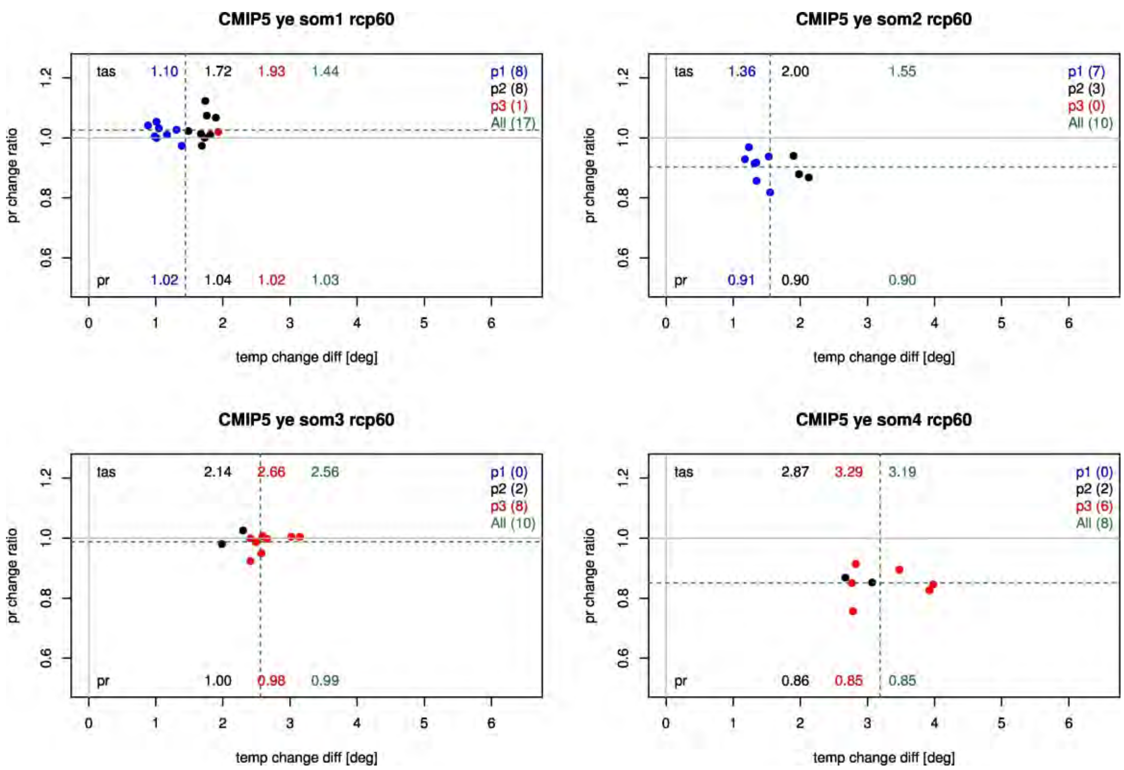


Figure ZD11. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the ZimBota Domain under RCP6.0 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 15 projections available in CMIP5 for RCP6.0.

Table ZD5a. Scenarios for the year over the ZimBota Domain under RCP6.0 based on Figure ZD11 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
60	1→3	1.00ºC/1.00	1.75ºC/1.05	2.75ºC/1.00
40	2→4	1.50ºC/0.90	2.50ºC/0.90	3.25ºC/0.85

Summary: Highest likelihood is for little change in rainfall, with decreased rainfall in the alternate warmer scenario.

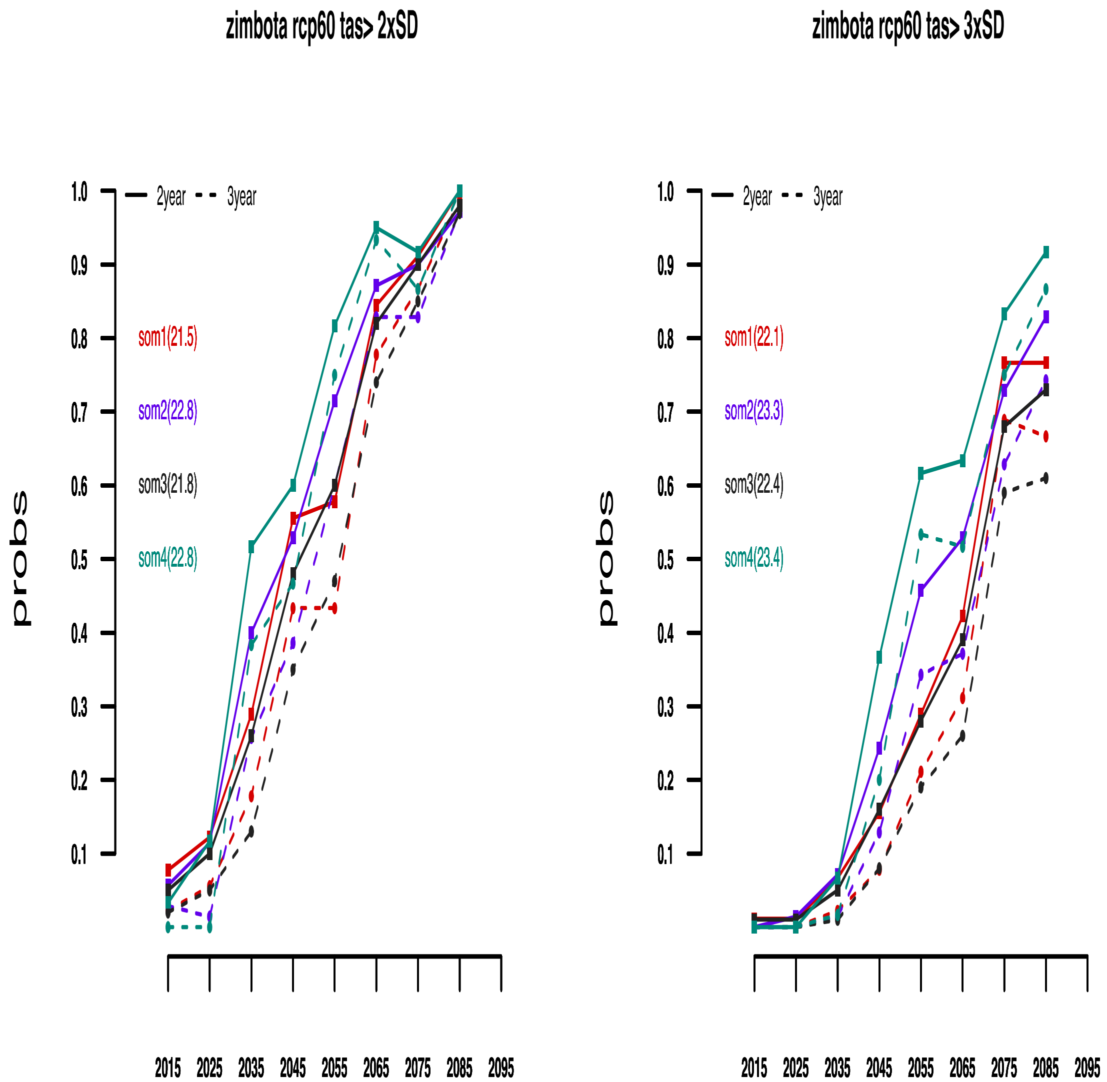


Figure ZD12. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD11 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

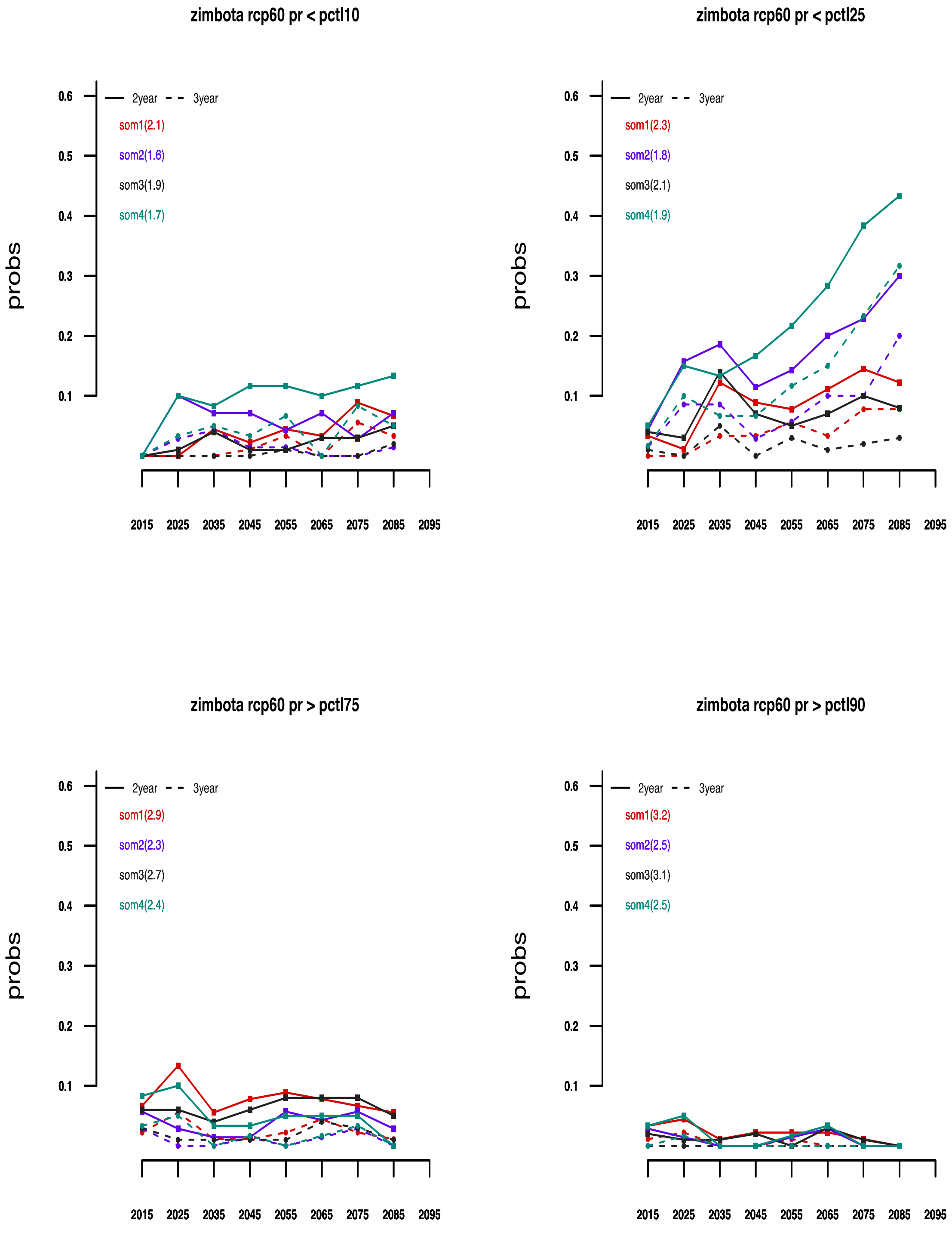


Figure ZD13. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD11 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

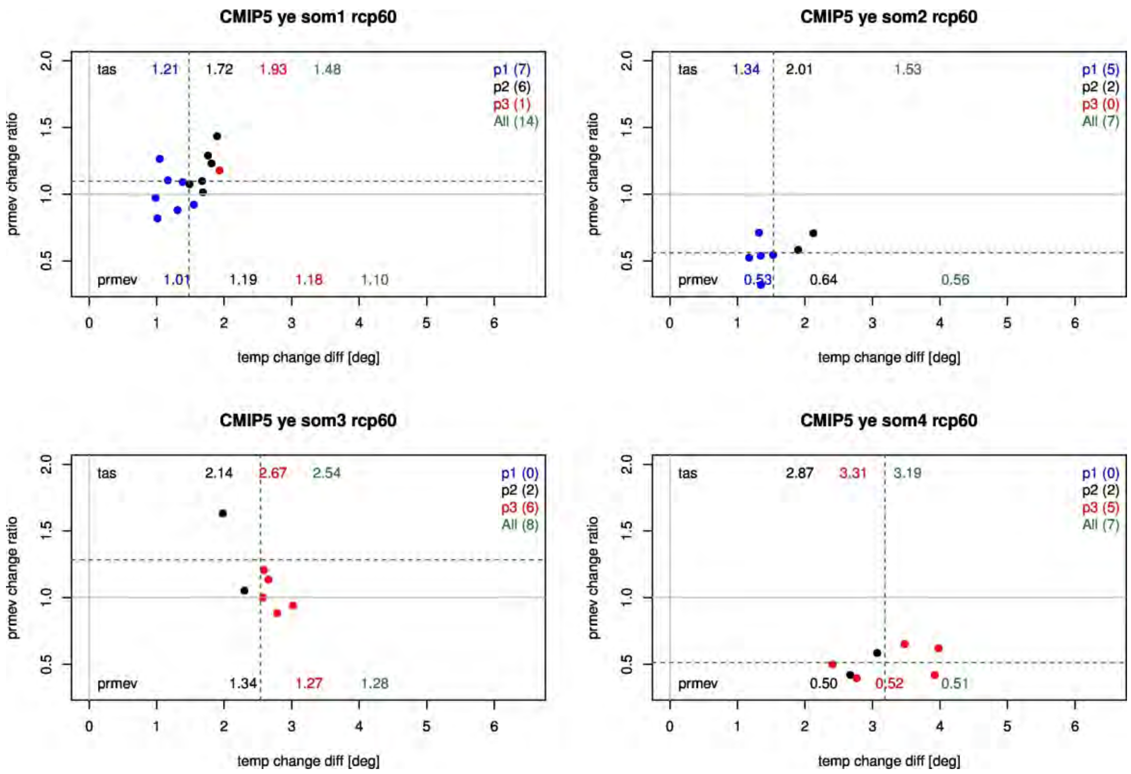


Figure ZD14. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the ZimBota Domain under RCP6.0; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 12 projections in CMIP5 for RCP6.0.

Table ZD6a. Scenarios for the year over the ZimBota Domain under RCP6.0 based on Figure ZD14 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
60	1→3	1.25ºC/1.00	2.00ºC/1.25	2.50ºC/1.25
40	2→4	1.25ºC/0.55	2.50ºC/0.55	3.25ºC/0.50

Summary: Some substantial changes in rainfall less evaporation in this relatively low populated set, especially in the decreases projected in the lesser-likelihood scenario from 2→4. Nevertheless a higher likelihood for an increase in rainfall less evaporation.

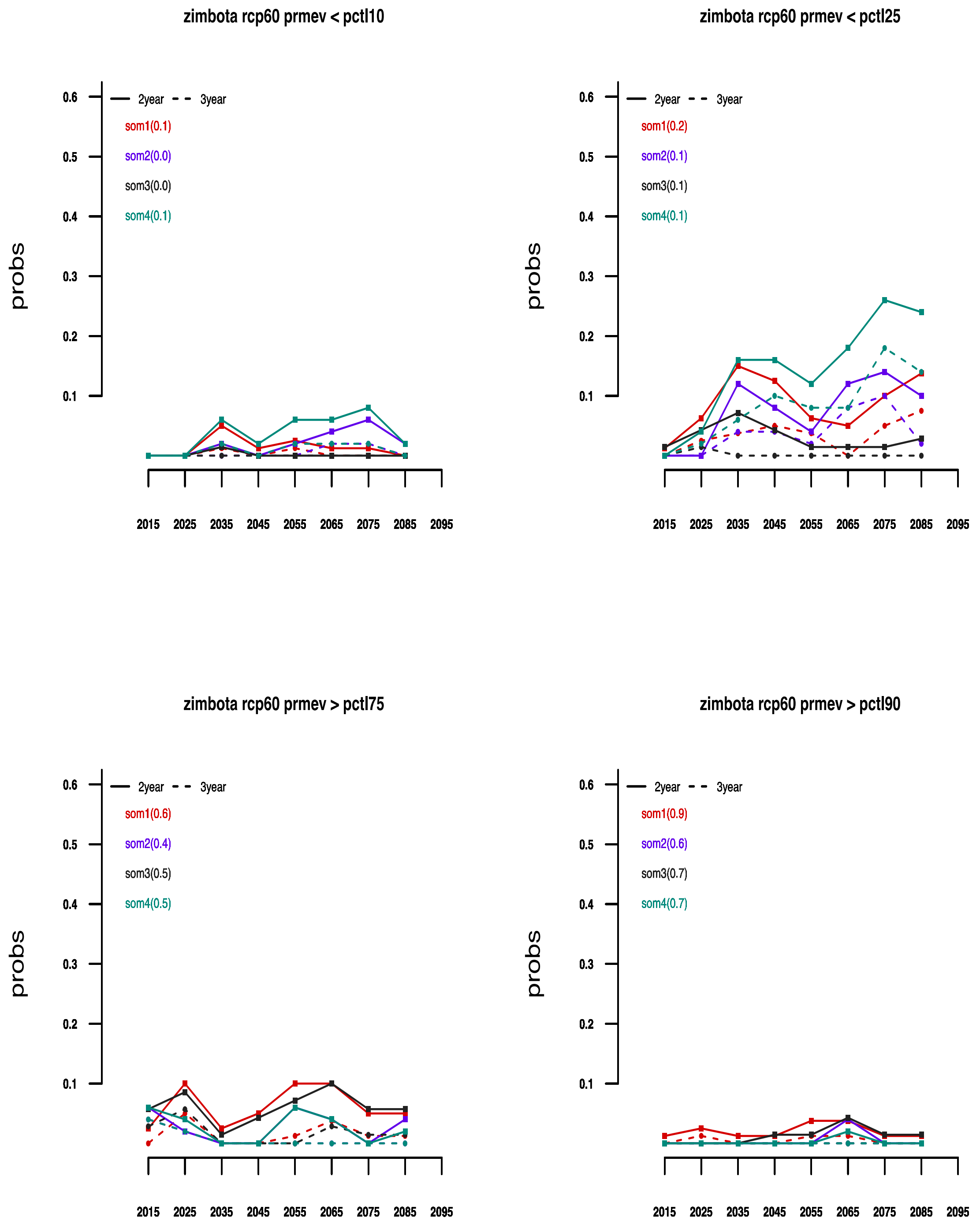


Figure ZD123. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD14 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP8.5; temperature vs rainfall

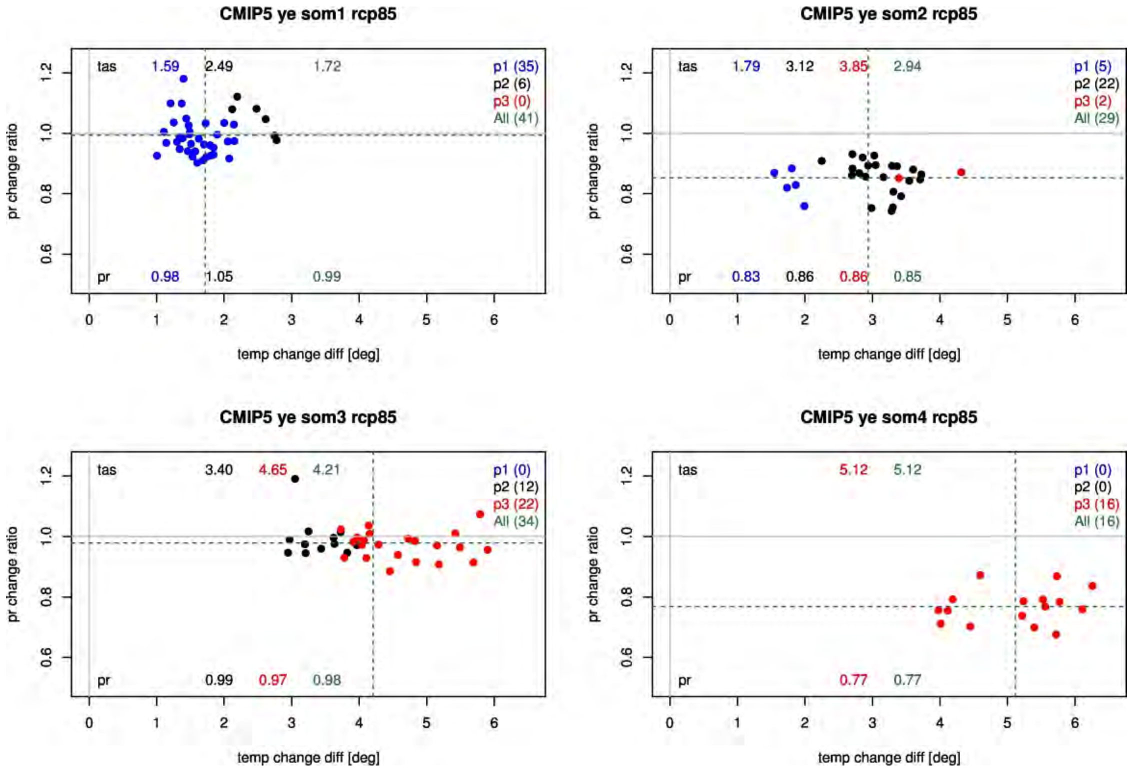


Figure ZD16. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the ZimBota Domain under RCP8.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 40 projections available in CMIP5 for RCP8.5.

Table ZD7a. Scenarios for the year over the ZimBota Domain under RCP8.5 based on Figure ZD16 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
55	1→2→4	1.50ºC/0.95	3.00ºC/0.90	5.00ºC/0.75
45	1→3	1.50ºC/1.00	3.00ºC/1.00	4.50ºC/0.95

Summary: Both scenarios, with somewhat similar likelihoods, ultimately lead to a drier climate.

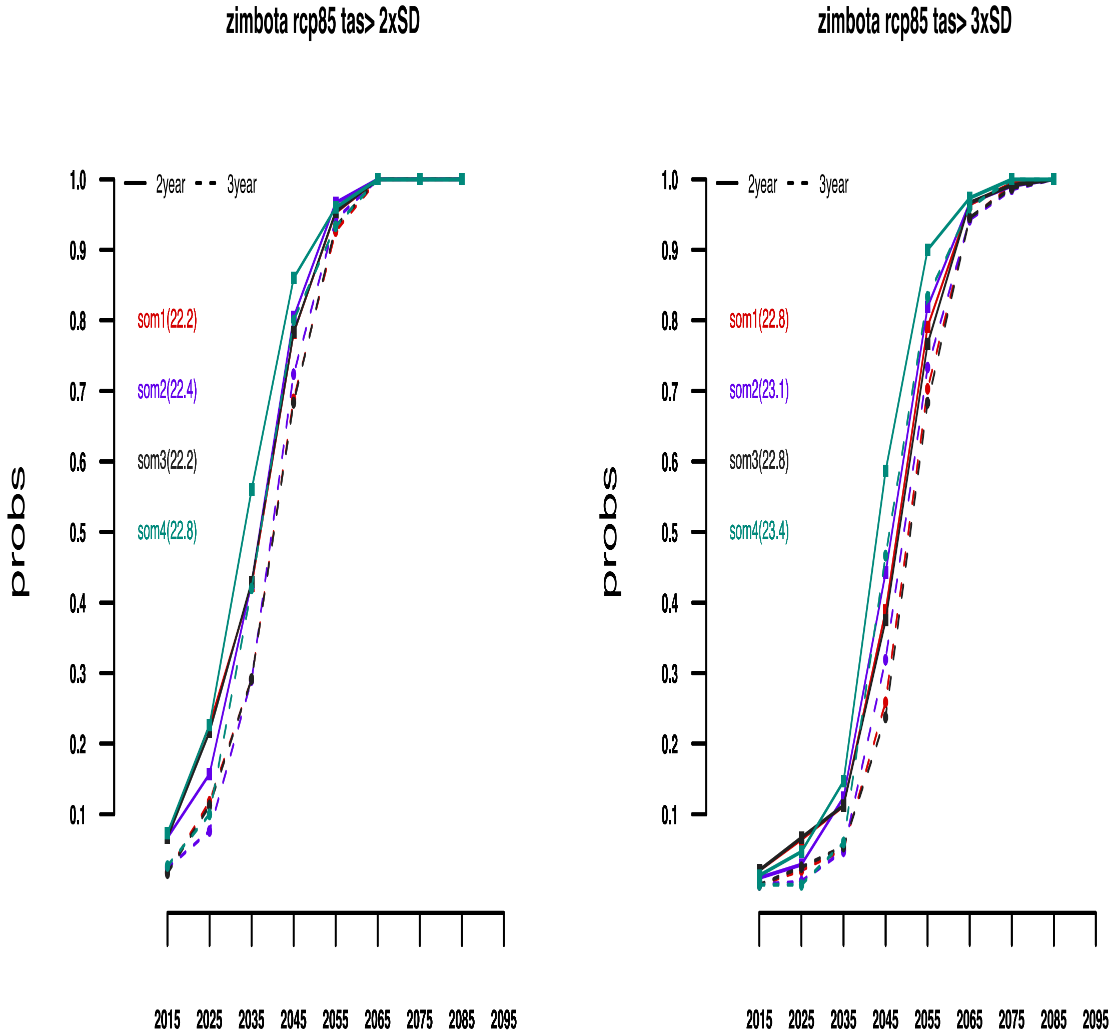


Figure ZD17. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD16 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP8.5; temperature vs rainfall

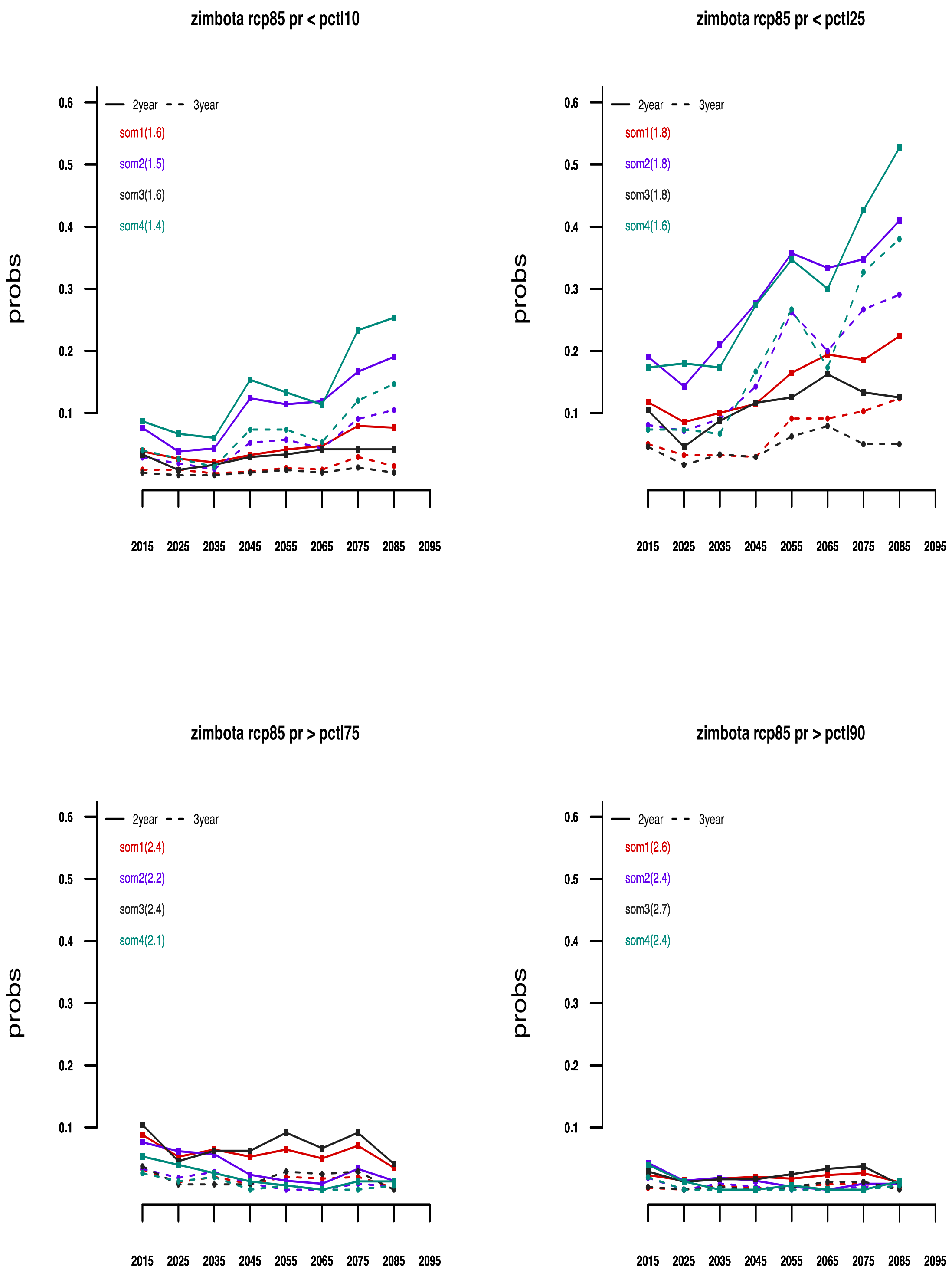


Figure ZD18. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD16 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

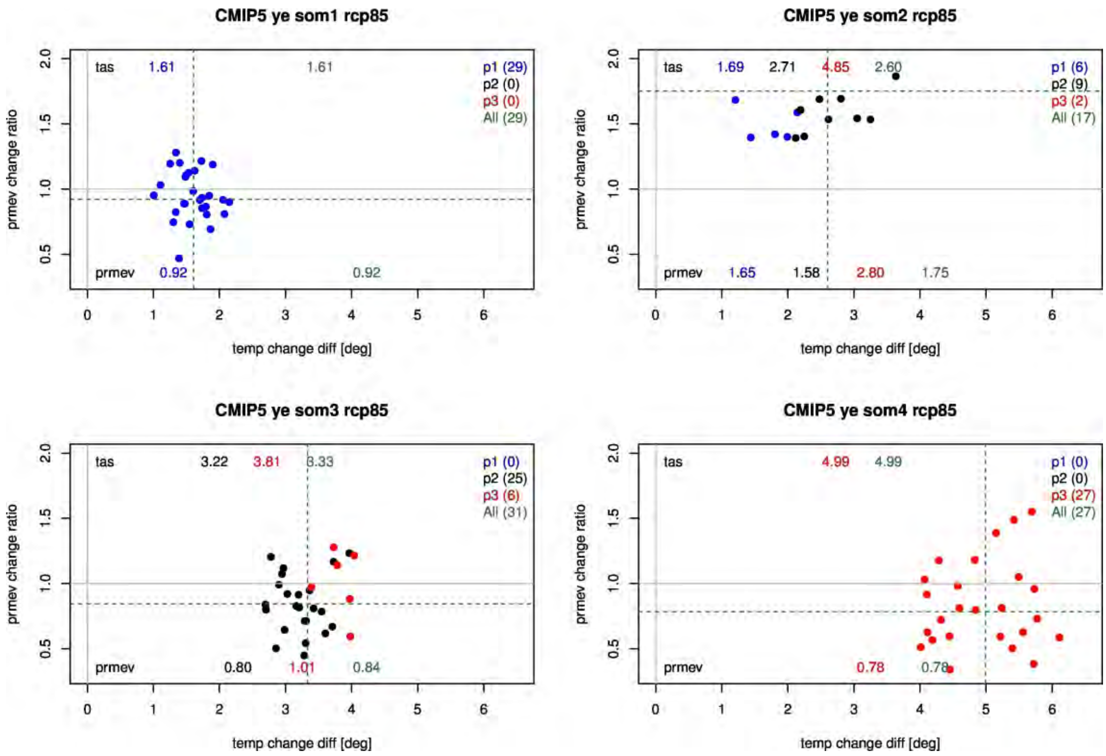


Figure ZD19. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the ZimBota Domain under RCP8.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 35 projections in CMIP5 for RCP8.5.

Table ZD8a. Scenarios for the year over the ZimBota Domain under RCP8.5 based on Figure ZD19 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
75	1→3→4	1.50ºC/0.90	3.25ºC/0.80	4.75ºC/0.80
25	1→2→4	1.50ºC/1.00	2.75ºC/1.60	5.00ºC/2.00

Summary: An unusual analysis in which both pathways start and end in the same soms (1 and 4 respectively) via the other two soms. Visually a distinct weighting towards a decrease in future rainfall less evaporation, indicated also in the higher-likelihood recommended scenario.

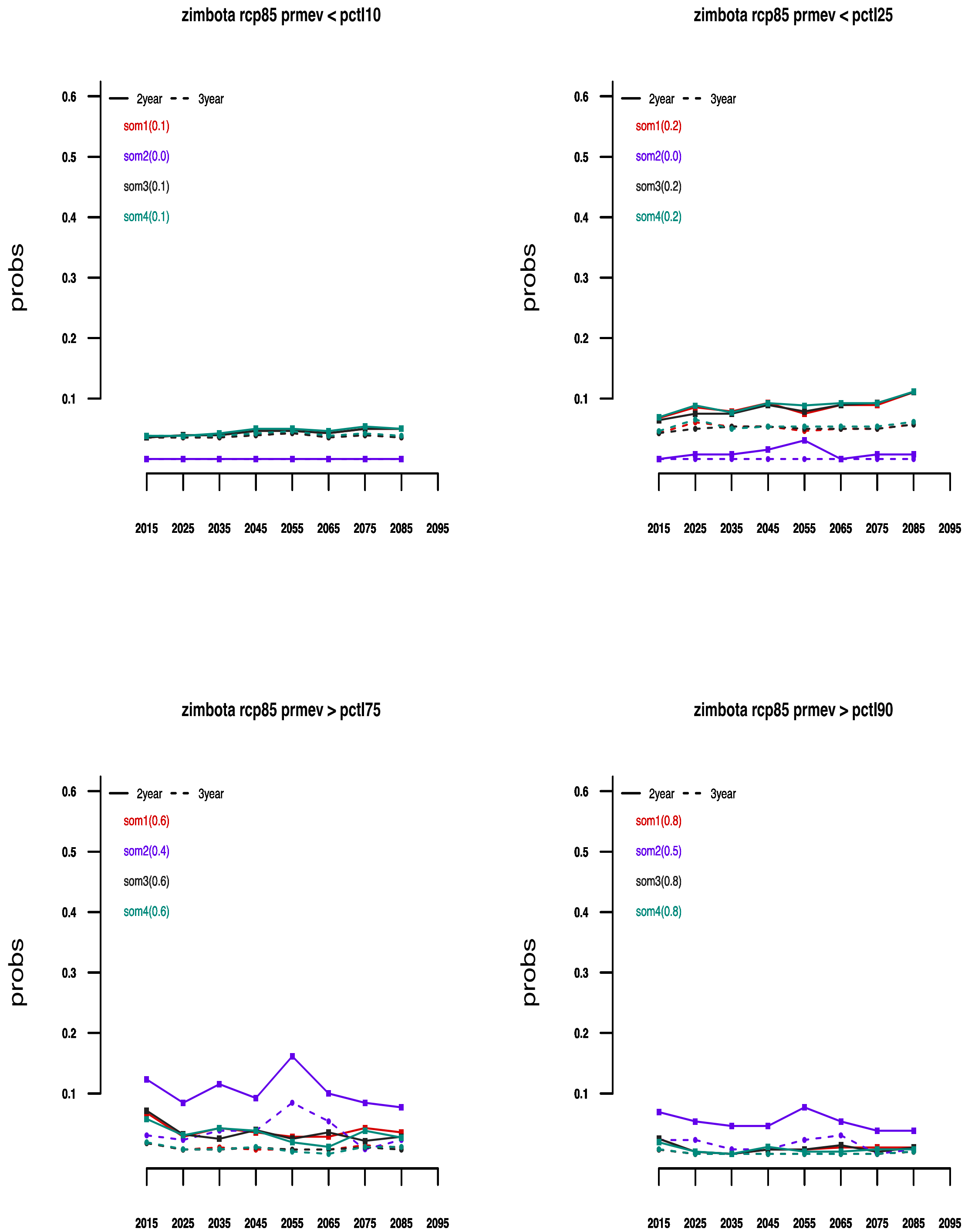


Figure ZD20. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ZD19 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

Self-Organising Maps Results for the Mpumalanga Domain

Introduction. Results are presented below for the analyses through self-organising maps (soms) for the Mpumalanga Domain. Assessments of soms analyses for each RCP and temperature vs rainfall or temperature vs rainfall less evaporation are presented individually towards the end of this document; RCPs start at 2.6 and increase successively, temperature vs rainfall is presented before temperature vs rainfall less evaporation. Results from the soms are charted on each page followed by a table giving suggested scenarios from these particular results; a brief justification for the suggested scenarios is provided below each table.

Immediately following this introductory section is a collation of the results from the soms tables for easy reference. Below the collated table for each RCP is a further table giving, for each individual soms analysis, two suggested extreme scenarios, derived entirely subjectively. These extreme scenarios focus on changes to rainfall or to rainfall less evaporation as appropriate and are an attempt to indicate possible scenarios representing greatest reasonable increases or decreases in rainfall or in rainfall less evaporation for that particular RCP. Note that had the focus been towards relatively high/low temperature increases different extreme scenarios would have been produced on at least some occasions. Thus the suggested extreme scenarios do not capture necessarily greatest and least changes in temperature projected for that RCP.

The number of projections for a given RCP, listed in the soms charts captions and repeated in the collation tables, may differ between the temperature against rainfall alone analyses and the temperature against rainfall less evaporation analyses for technical reasons.

Also provided following the tables of recommended scenarios for each RCP overall, and towards the end of this document for individual soms under each RCP, are results for the inter-annual variability (IAV) calculations. These illustrate future decadal probabilities that in successive two- and three-year periods:

- annual temperatures will exceed +2 and +3 standard deviations
- annual rainfall totals or rainfall less evaporation values will be below the 10th and 25th percentiles
- annual rainfall totals or rainfall less evaporation values will be above the 75th and 90th percentiles

relative to values across the base period of 1979-2005. Temperature probabilities have been presented only for the temperature vs rainfall soms as those for the temperature vs rainfall less evaporation soms are equivalent. Details of these charts are discussed further in the main document. Equivalent charts of IAV calculations for each RCP in total are provided immediately following the summary tables and before details of individual RCPs.

Summary of results.

Temperature against rainfall. As might be expected, temperatures in the RCP scenarios increase with emissions, a rise that is, in general, greater for the drier scenarios, although this is not reflected fully in the recommended scenarios. Rainfall changes in both directions appear in all suggested scenarios for individual RCPs, although the marginally higher likelihoods in general are for little change in the two higher RCPs but for a decrease in the other two.

Temperatures in the recommended extreme scenarios increase in general with RCP; rainfall changes in the increased scenarios tend to be projected to be above current levels, by up to about 10%.

Decreases of rainfall in the extreme scenarios are somewhat larger than the corresponding increases, typically 10-30%.

Likelihoods of annual temperatures exceeding two and three standard deviations calculated across the base period of 1979-2005 increase, naturally, with RCP (see Figure MA), but vary also according to individual soms (see diagrams in the sections for the individual RCPs). Under RCP8.5 successive two and three year periods are almost certain by the 2070's for two standard deviations and by the 2080's for three standard deviations. By contrast, under RCP2.6 only one of the soms produces probabilities reaching almost 90% (by the 2050's) for two standard deviations whether over two or over three year periods, whereas for three standard deviations probabilities peak for just one som at around 50%. For RCP4.5 and RCP6.0 100% probabilities are reached only by the end of the century but for RCP8.5 all soms project 100% probabilities by the same times.

Likelihoods of annual rainfall totals outside the 10th and 90th percentiles over 2 and 3 years increase/decrease slightly respectively with high RCPs, in general being below 10% (see Figure MB). Similar increasing/decreasing trends of these likelihoods in time are in general apparent for all individual RCPs also, but there is also distinct differences in likelihoods for individual soms (see diagrams in the sections for the individual RCPs). For many soms likelihoods remain below 10% throughout but for certain ones these may rise towards 30% or higher. The results suggest future increased spread of rainfall distributions with more extended drier periods and reduced numbers of wetter periods.

Temperature against rainfall less evaporation. The picture is a little more complex for rainfall less evaporation, with drier conditions having the higher likelihoods except for the lesser-populated RCP6.0. In all cases other than RCP6.0 some substantial increases in rainfall less evaporation are projected by some models, but in all cases these are with lower likelihood, i.e. they are projected by a small number of models that might be viewed as outliers to the main set of projections.

Temperatures in the suggested extreme scenarios increase in general with RCP. Marked decreases in water availability are suggested in the decreased extremes scenarios for all RCPs, with some large increases possible also all RCPs.

Likelihoods of annual rainfall less evaporation amounts outside the 10th and 90th percentiles over 2 and 3 years, as similarly for rainfall totals, do not change substantially, in general being below 10% but perhaps are increased above there towards the end of the century for the higher RCPs (see Figure MC). However there are increasing/decreasing respectively likelihoods of 2/3 year values outside the 25th and 75th percentiles as the century proceeds, again especially for RCP6.0 and RCP8.5 (see Figures in individual sections). There does seem to be a slight weighting towards greater likelihoods for below the 25th percentile than for above the 75th, i.e. a skewing towards drier conditions. For many soms likelihoods in either direction remain below 10% throughout, but for some they may reach 30% or more.

Conclusions. In section 3 of the main report it was noted that the Mpumalanga Domain sits on the western flank of higher ground in north-central South Africa at a location where most ensemble means for all RCPs suggest future rainfall decreases on all time scales, although the Domain lies just north of a region with increases in the ensemble means. For rainfall less evaporation the ensemble mean values vary roughly equally in both sign and magnitude. Rainfall decreases have been given the higher likelihoods in the recommended scenarios, expect for rainfall for the RCP8.5 scenario, and in all cases for the rainfall less evaporation scenarios. The reason is clear in the soms analyses, that the full sets of projections are skewed towards drier conditions such that the ensemble means are weighted against the substantial numbers of projections for relatively limited increases.

Across RCP2.6, RCP4.5 and RCP6.0 there is some consistency between suggested scenarios in terms of adjustments in rainfall and in rainfall less evaporation notwithstanding small increases in temperature with rising emissions. As found in most other areas for which the soms technique has been applied RCP8.5 stands out somewhat, both in terms of higher temperature increases as well as in adjustments to rainfall/rainfall less evaporation which tend to be more substantially negative, and additionally for rainfall less evaporation positive. Hence the recommendations below are weighted away from RCP8.5. Overall the recommendations suggest approximately slightly higher prospects of decreased over increased water availability according to both analyses. However, decreases in water availability according to the rainfall less evaporation assessments might be more significant than under the rainfall alone assessments, as the former take into consideration increased evaporation as temperatures rise.

If there is a requirement to examine projected changes under RCP8.5 then use the recommended and extreme scenarios repeated from the appropriate collated tables below.

The IAV calculations indicate steady increases in time in likelihoods of extended 2- and 3-year spells of temperatures above historical annual 2 and 3 standard deviations, greater with higher RCPs and reaching 100% in many cases towards the end of the century. Both for rainfall and for rainfall less evaporation likelihoods of extended 2- and 3-years spells below and above historical annual 10th and 90th percentiles do not change significantly in time, but those for the 25th and 90th percentiles do (although not for all soms), suggesting an increase in spread of annual values with possible slight bias towards drier conditions.

Recommended Scenarios for the Mpumalanga Domain based on RCP2.6, RCP4.5 and RCP6.0

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
60	1.25ºC/0.95	1.50ºC/0.95	2.00ºC/0.90
40	1.00ºC/1.05	1.50ºC/1.05	2.25ºC/1.00

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall changes)

	2040	2065	2080
Increased	1.00ºC/1.10	1.50ºC/1.10	2.00ºC/1.10
Decreased	1.25ºC/0.90	2.00ºC/0.85	2.25ºC/0.85

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
55	1.25ºC/0.90	1.50ºC/0.75	2.00ºC/0.85
45	0.75ºC/1.10	1.50ºC/1.10	2.00ºC/1.25

Extreme scenarios based on temperature against rainfall less evaporation analyses (focussed primarily on rainfall less evaporation changes)

	2040	2065	2080
Increased	1.00ºC/1.50	1.50ºC/1.70	2.25ºC/1.70
Decreased	1.50ºC/0.70	2.00ºC/0.60	2.50ºC/0.60

Recommended Scenarios for the Mpumalanga Domain based on RCP8.5

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
55	1.50ºC/1.05	3.00ºC/1.00	4.25ºC/1.00
45	1.50ºC/0.95	2.75ºC/0.90	4.50ºC/0.80

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall changes)

	2040	2065	2080
Increased	1.25ºC/1.10	2.25ºC/1.10	4.50ºC/1.05
Decreased	1.50ºC/0.90	2.20ºC/0.85	5.00ºC/0.75

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
85	1.50ºC/0.95	2.75ºC/1.00	4.50ºC/0.85
15	1.50ºC/1.90	3.00ºC/2.25	5.50ºC/2.50

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall less evaporation changes)

	2040	2065	2080
Increased	1.50ºC/1.50	2.75ºC/1.75	3.50ºC/2.00
Decreased	1.25ºC/0.60	2.75ºC/0.50	4.25ºC/0.50

Scenarios from each RCP for the Mpumalanga Domain based on analyses of temperature against rainfall to the left and on analyses of temperature against rainfall less evaporation to the right; in the summaries following each table TR refers to the temperature/rainfall table to the left and TRLE to the temperature/rainfall less evaporation table to the right. Following the RCP header are the numbers of projections available to produce TR and TRLE respectively. Note that the soms numbers in the second columns of each individual table are arbitrary and should not be used to inter-compare TR and TRLE.

RCP2.6 – 20 and 18 projections

	%		2040	2065	2080		%		2040	2065	2080
1	30	4	0.75ºC/1.05	1.00ºC/1.05	1.00ºC/1.05		40	3	0.75ºC/1.10	1.00ºC/1.00	1.00ºC/0.95
2	30	2	1.25ºC/0.95	1.25ºC/0.95	1.25ºC/0.95		35	1	1.25ºC/0.85	1.25ºC/0.75	1.50ºC/0.80
3	25	1	0.75ºC/0.95	0.75ºC/0.95	0.75ºC/0.95		15	4	0.75ºC/1.60	1.50ºC/1.75	1.50ºC/1.75
4	15	3	1.75ºC/0.90	2.00ºC/0.90	2.00ºC/0.90		10	2	1.75ºC/0.75	2.00ºC/0.70	2.00ºC/0.80

Summary: According to the TR scenarios a decrease in water availability is perhaps the most likely future in this Domain. From TRLE, on the other hand, there is a rough balance between increased and decreased rainfall less evaporation likelihoods, although all scenarios excepting one with relatively low likelihood (Line 3) end with a decrease.

Suggested extreme scenarios for RCP2.6 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.00ºC/1.10	1.00ºC/1.10	1.00ºC/1.10		1.00ºC/1.70	1.00ºC/1.70	1.25ºC/1.70
Decreased	1.25ºC/0.90	2.00ºC/0.85	2.00ºC/0.85		1.75ºC/0.80	2.00ºC/0.75	2.00ºC/0.70

RCP4.5 – 38 and 32 projections

	%		2040	2065	2080		%		2040	2065	2080
1	65	1→3	1.25ºC/0.95	1.75ºC/0.95	2.00ºC/0.95		85	1→2→4	1.25ºC/0.95	1.75ºC/0.90	2.25ºC/0.90
2	35	2→4	1.25ºC/1.05	2.00ºC/1.05	2.50ºC/1.05		15	3	1.50ºC/1.75	2.00ºC/1.80	2.25ºC/1.85

Summary: In both suggested scenarios there is a marked weighting towards a future decrease in available water resources.

Suggested extreme scenarios for RCP4.5 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.25ºC/1.05	1.50ºC/1.10	2.50ºC/1.10		1.25ºC/1.50	2.00ºC/1.80	2.50ºC/1.80

Decreased	1.25ºC/0.90	2.25ºC/0.85	2.25ºC/0.85		1.25ºC/0.60	2.00ºC/0.60	2.25ºC/0.60

RCP6.0 – 15 and 12 projections

	%		2040	2065	2080		%		2040	2065	2080
1	60	1→3	1.00ºC/1.05	1.50ºC/1.10	2.50ºC/1.00		85	1→2→4	1.00ºC/0.95	1.75ºC/1.05	2.50ºC/1.15
2	40	2→4	1.25ºC/0.95	2.00ºC/0.90	3.00ºC/0.85		15	3	1.50ºC/0.30	2.25ºC/0.30	3.25ºC/0.30

Summary: One of the more notable aspects of this to be taken into consideration is the relatively small number of projections available, which gives relatively less confidence in these results. Nevertheless, highest likelihood in both cases is for water resources to be maintained or increased. The substantial reduction suggested by the lower-likelihood TRLE scenario (Line 2) needs to be treated with caution.

Suggested extreme scenarios for RCP6.0 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.00ºC/1.05	1.50ºC/1.05	2.25ºC/1.05		1.00ºC/1.30	1.75ºC/1.50	2.50ºC/1.50
Decreased	1.00ºC/0.95	2.00ºC/0.90	2.75ºC/0.85		1.00ºC/0.50	2.00ºC/0.50	2.75ºC/0.50

RCP8.5 – 40 and 32 projections

	%		2040	2065	2080		%		2040	2065	2080
1	55	1→4	1.50ºC/1.05	3.00ºC/1.00	4.25ºC/1.00		85	1→3→4	1.50ºC/0.95	2.75ºC/1.00	4.50ºC/0.85
2	45	2→3	1.50ºC/0.95	2.75ºC/0.90	4.50ºC/0.80		15	2	1.50ºC/1.90	3.00ºC/2.25	5.50ºC/2.50

Summary: In the TR scenarios there is a weighting towards an increase, or at least little change, in rainfall whereas in TRLE it is towards a decrease in rainfall less evaporation. A small number of the TRLE simulations suggest high increases in rainfall less evaporation, but there must be a suspicion that this results in part from relatively small differences between these values in the base period.

Suggested extreme scenarios for RCP8.5 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.25ºC/1.10	2.25ºC/1.10	4.50ºC/1.05		1.50ºC/1.50	2.75ºC/1.75	3.50ºC/2.00
Decreased	1.50ºC/0.90	2.20ºC/0.85	5.00ºC/0.75		1.25ºC/0.60	2.75ºC/0.50	4.25ºC/0.50

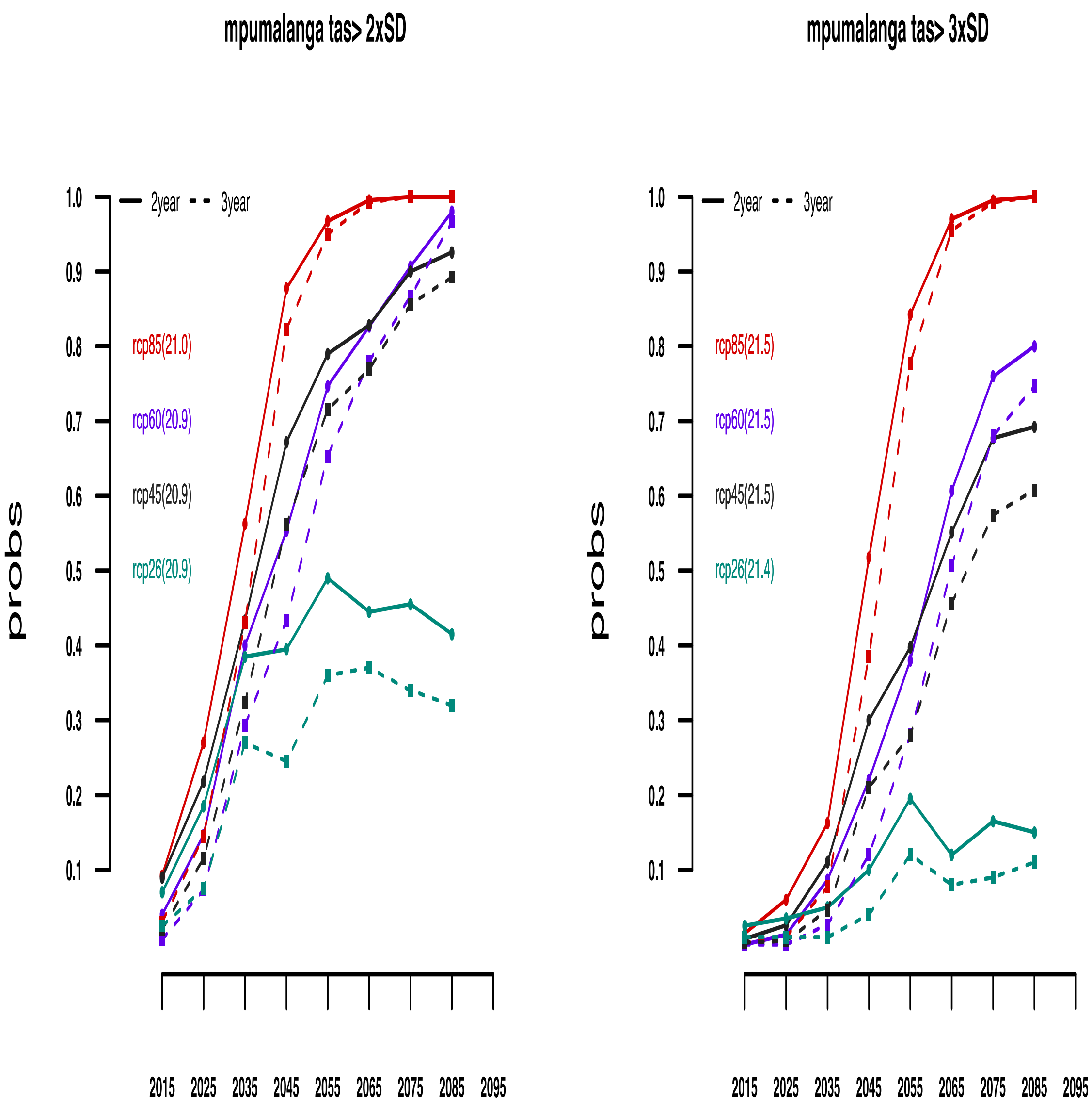


Figure MA. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes.

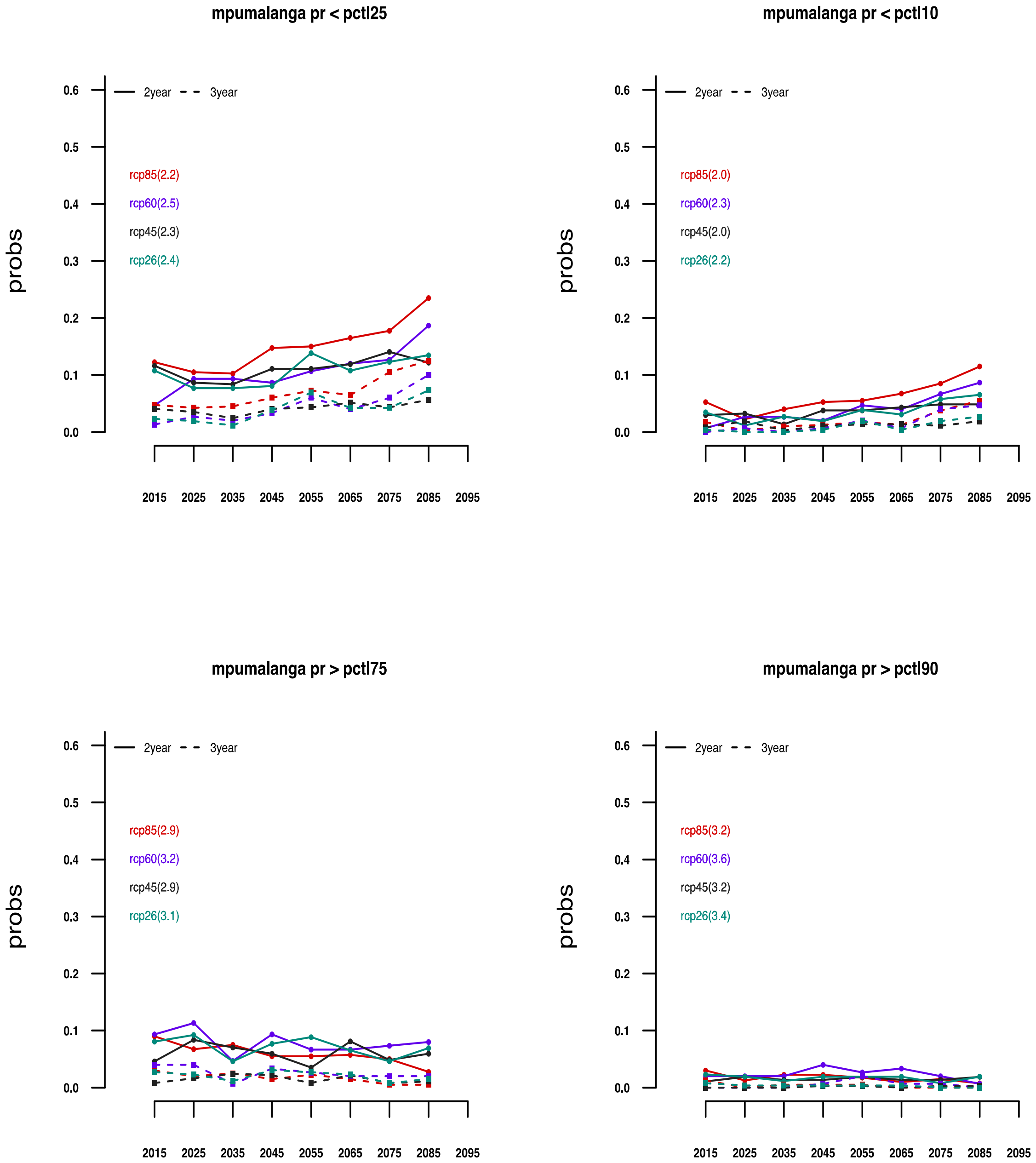


Figure MB. Decadal probabilities that future annual rainfall totals will be below the 25th percentile (top left) or the 10th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the RCP numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

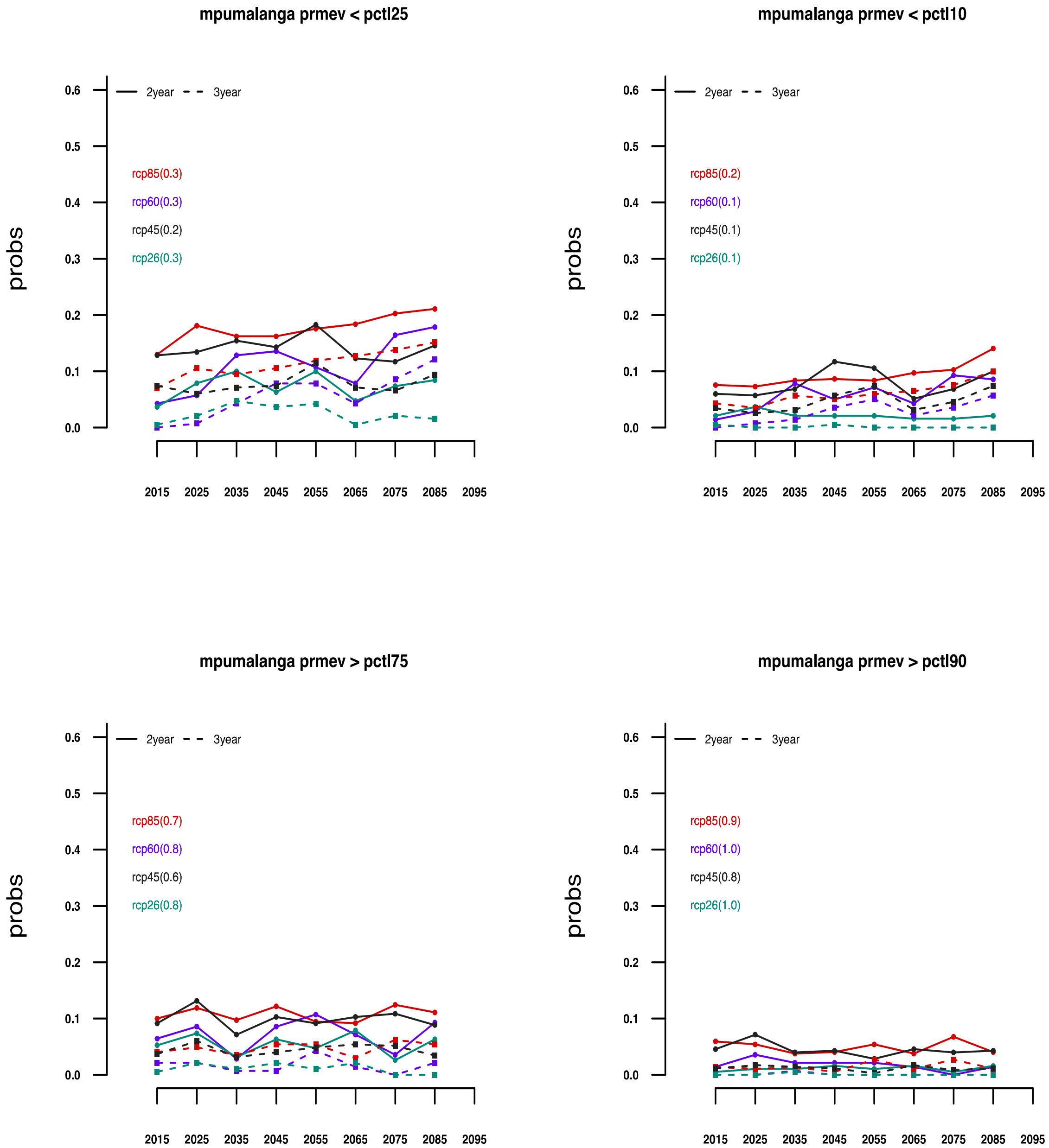


Figure MC. Decadal probabilities that future annual rainfall less evaporation totals will be below the 25th percentile (top left) or the 10th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the RCP numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP2.6; temperature vs rainfall

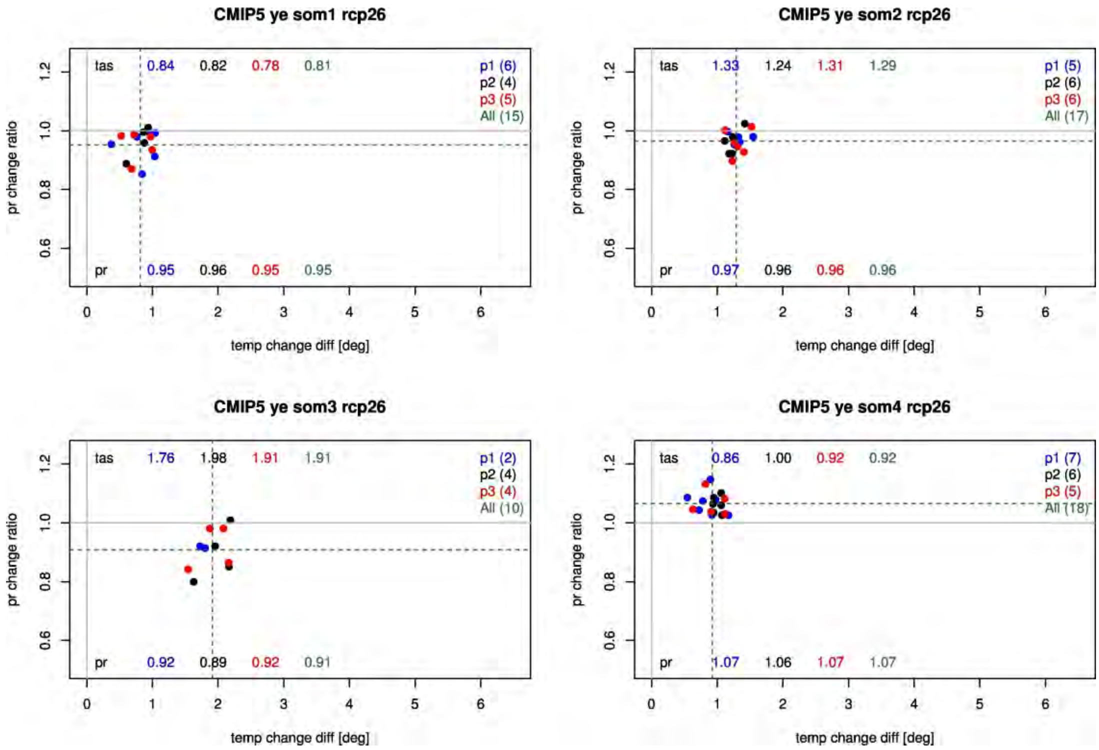
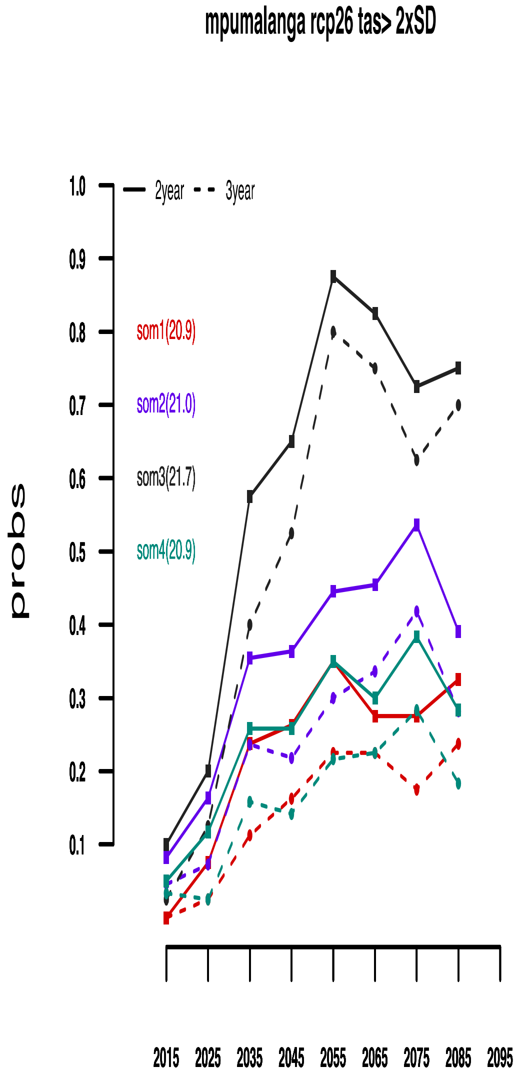


Figure MD1. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Mpumalanga Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 20 projections available in CMIP5 for RCP2.6.

Table MD1a. Scenarios for the year over the Mpumalanga Domain under RCP2.6 based on Figure MD1 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
30	4	0.75ºC/1.05	1.00ºC/1.05	1.00ºC/1.05
30	2	1.25ºC/0.95	1.25ºC/0.95	1.25ºC/0.95
25	1	0.75ºC/0.95	0.75ºC/0.95	0.75ºC/0.95
15	3	1.75ºC/0.90	2.00ºC/0.90	2.00ºC/0.90

Summary: Each som appears to form an individual pathway, with similar likelihoods in the top 3 soms. Som 4, with marginally the highest likelihood (although not reflected in Table MD1a), suggests a slight increase in rainfall, but all others, with combined likelihood estimated at 70%, point to future decreases.



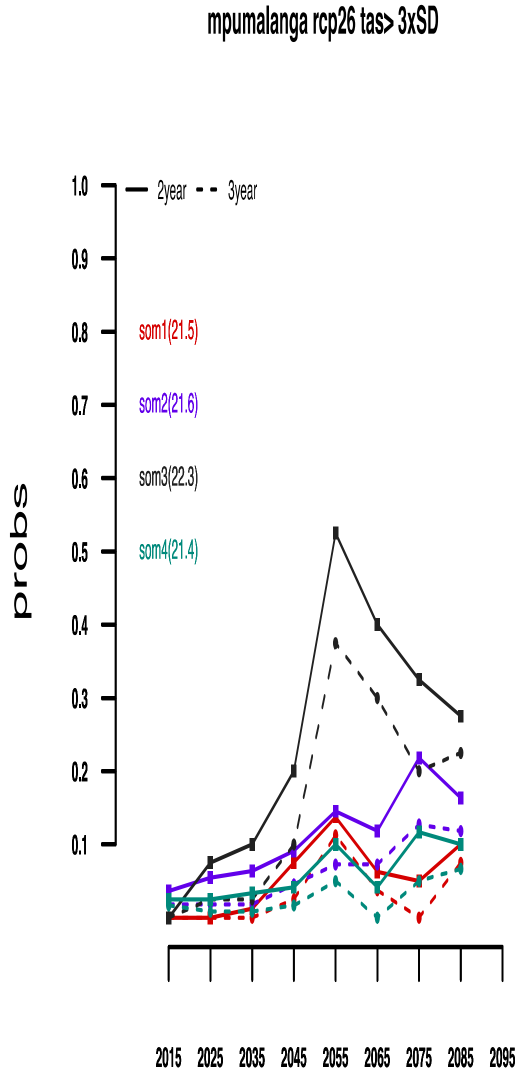


Figure MD24. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD1 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

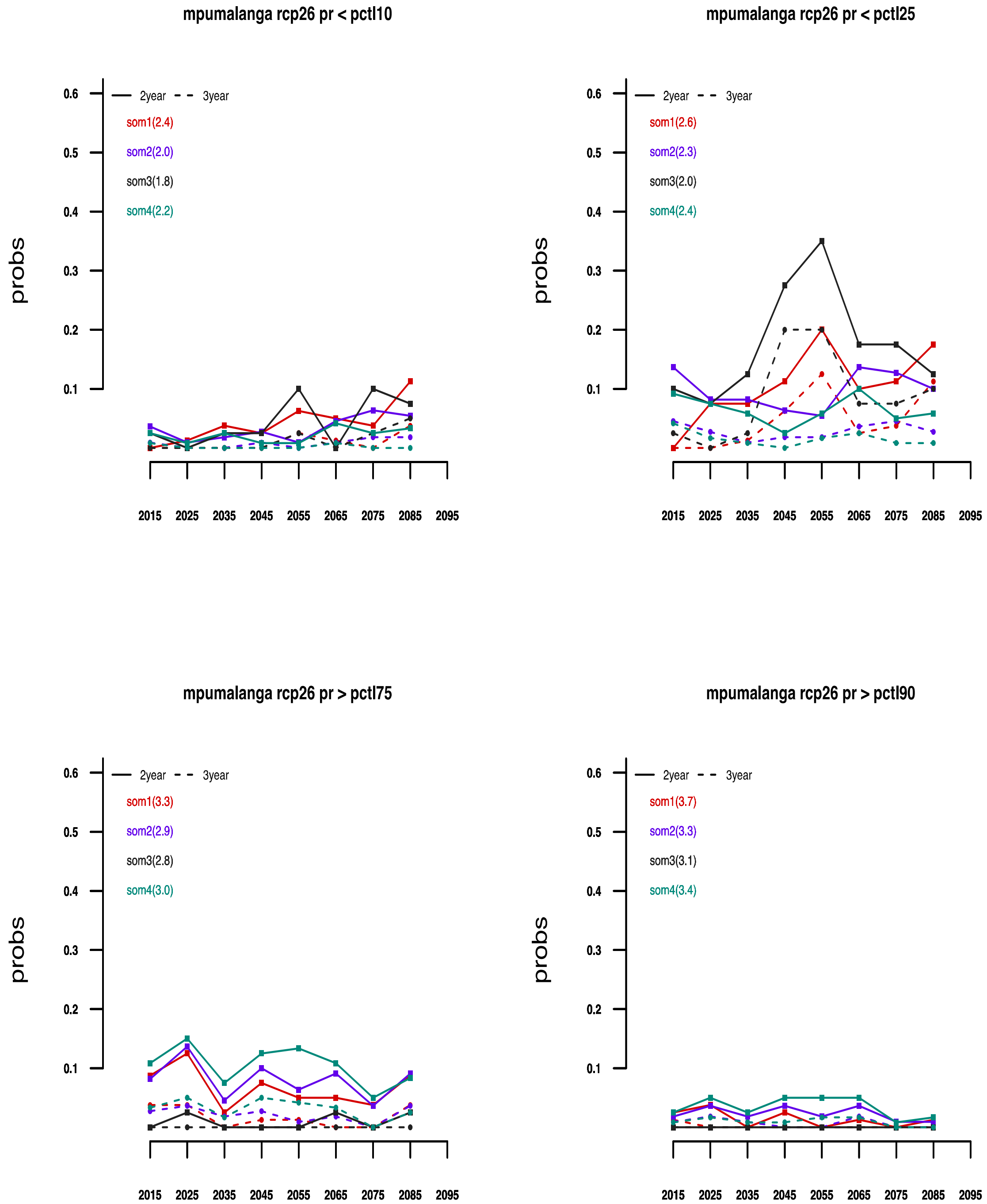


Figure MD25. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD1 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

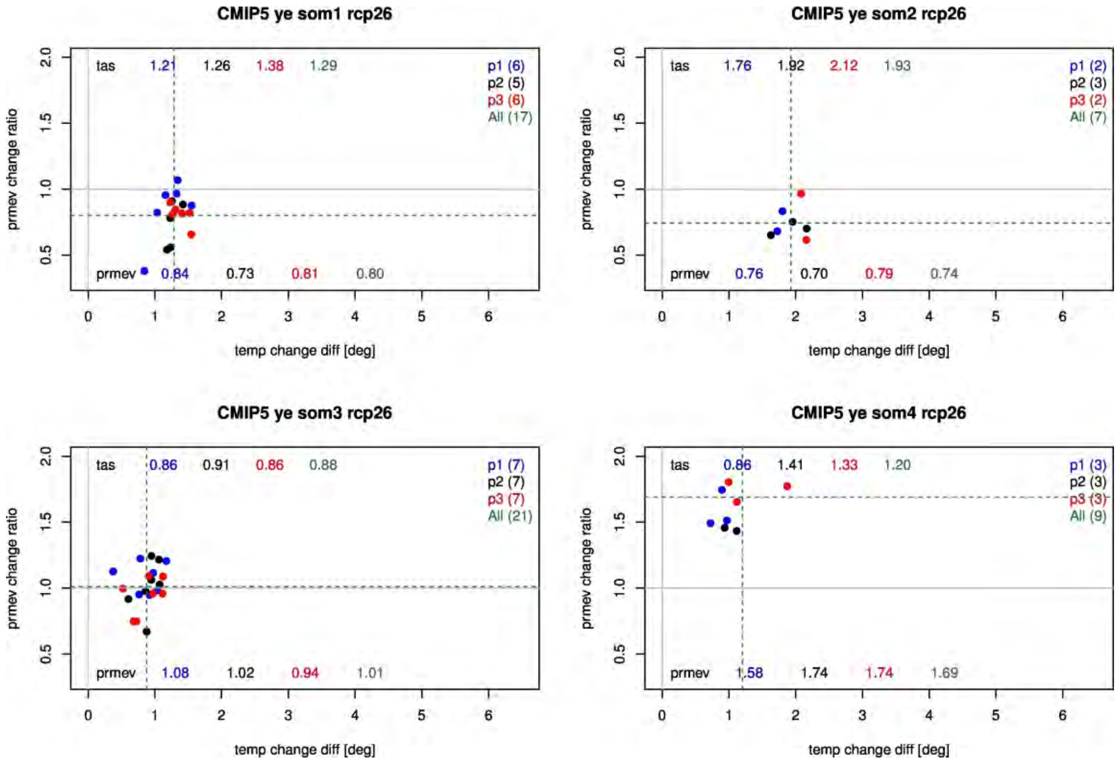


Figure MD4. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Mpumalanga Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 18 projections available in CMIP5 for RCP2.6.

Table MD2a. Scenarios for the year over the Mpumalanga Domain under RCP2.6 based on Figure MD4 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
40	3	0.75ºC/1.10	1.00ºC/1.00	1.00ºC/0.95
35	1	1.25ºC/0.85	1.25ºC/0.75	1.50ºC/0.80
15	4	0.75ºC/1.60	1.50ºC/1.75	1.50ºC/1.75
10	2	1.75ºC/0.75	2.00ºC/0.70	2.00ºC/0.80

Summary: Four scenarios with each som producing its own pathway. A roughly equal split of likelihoods between an increase in rainfall less evaporation (soms 3 and 4) and a decrease (soms 1 and 2). One projection sits on its own (som 4) with a substantial increase in rainfall less evaporation.

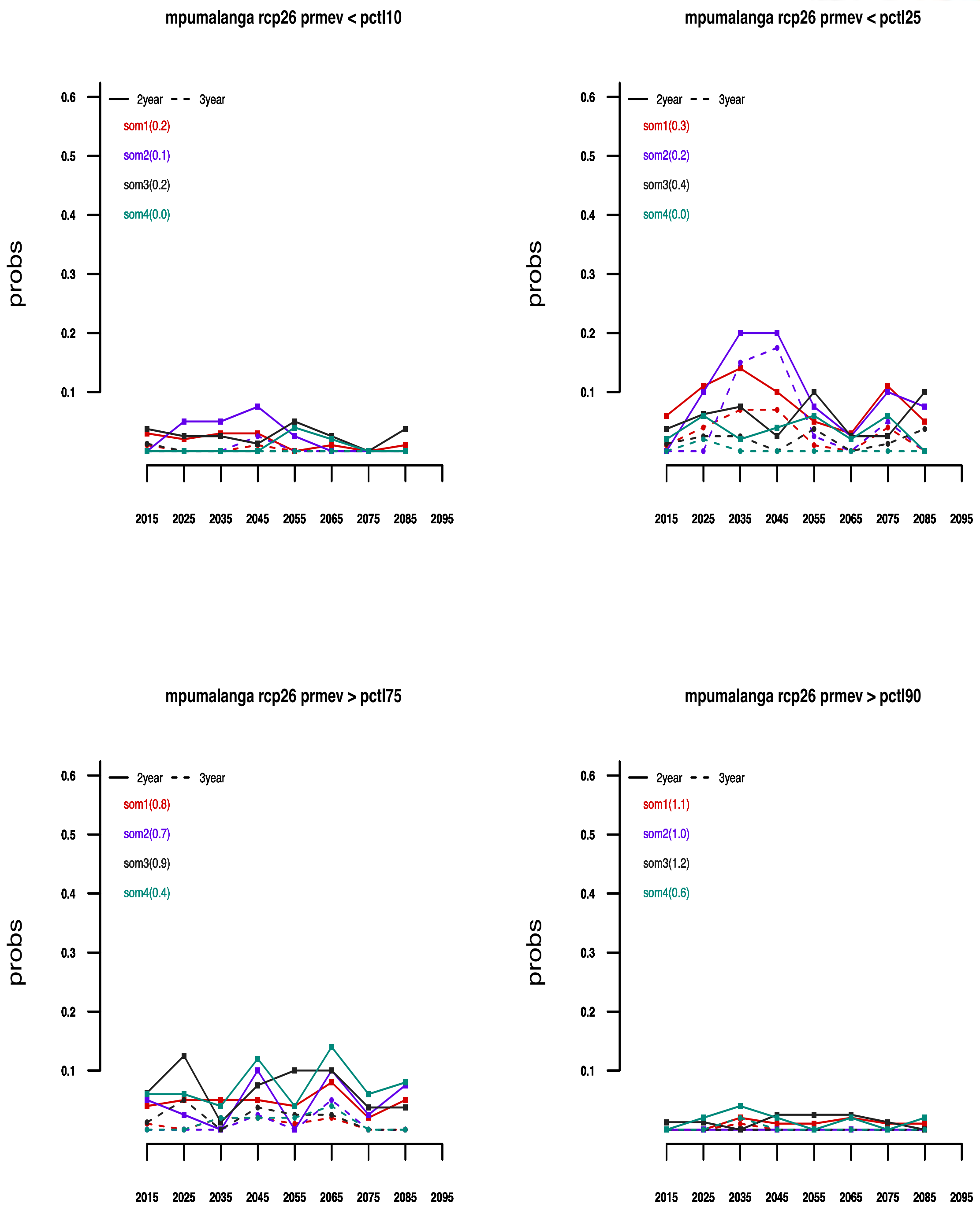


Figure MD26. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD3 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall

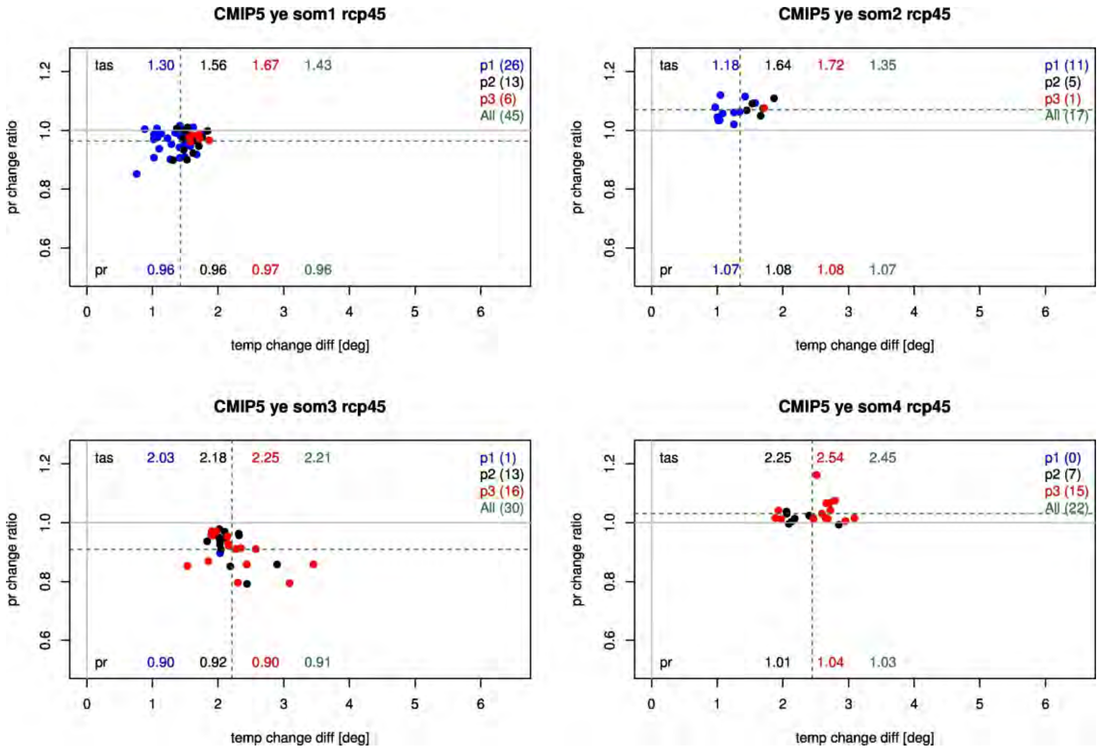


Figure MD6. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Mpumalanga Domain under RCP4.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 38 projections available in CMIP5 for RCP4.5.

Table MD3a. Scenarios for the year over the Mpumalanga Domain under RCP4.5 based on Figure MD6 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
65	1→3	1.25ºC/0.95	1.75ºC/0.95	2.00ºC/0.95
35	2→4	1.25ºC/1.05	2.00ºC/1.05	2.50ºC/1.05

Summary: Two scenarios, both with about 5% changes in rainfall with the higher likelihood towards a decrease. Note that this set is uncommon in that the warmer scenarios are those with increased rainfall.

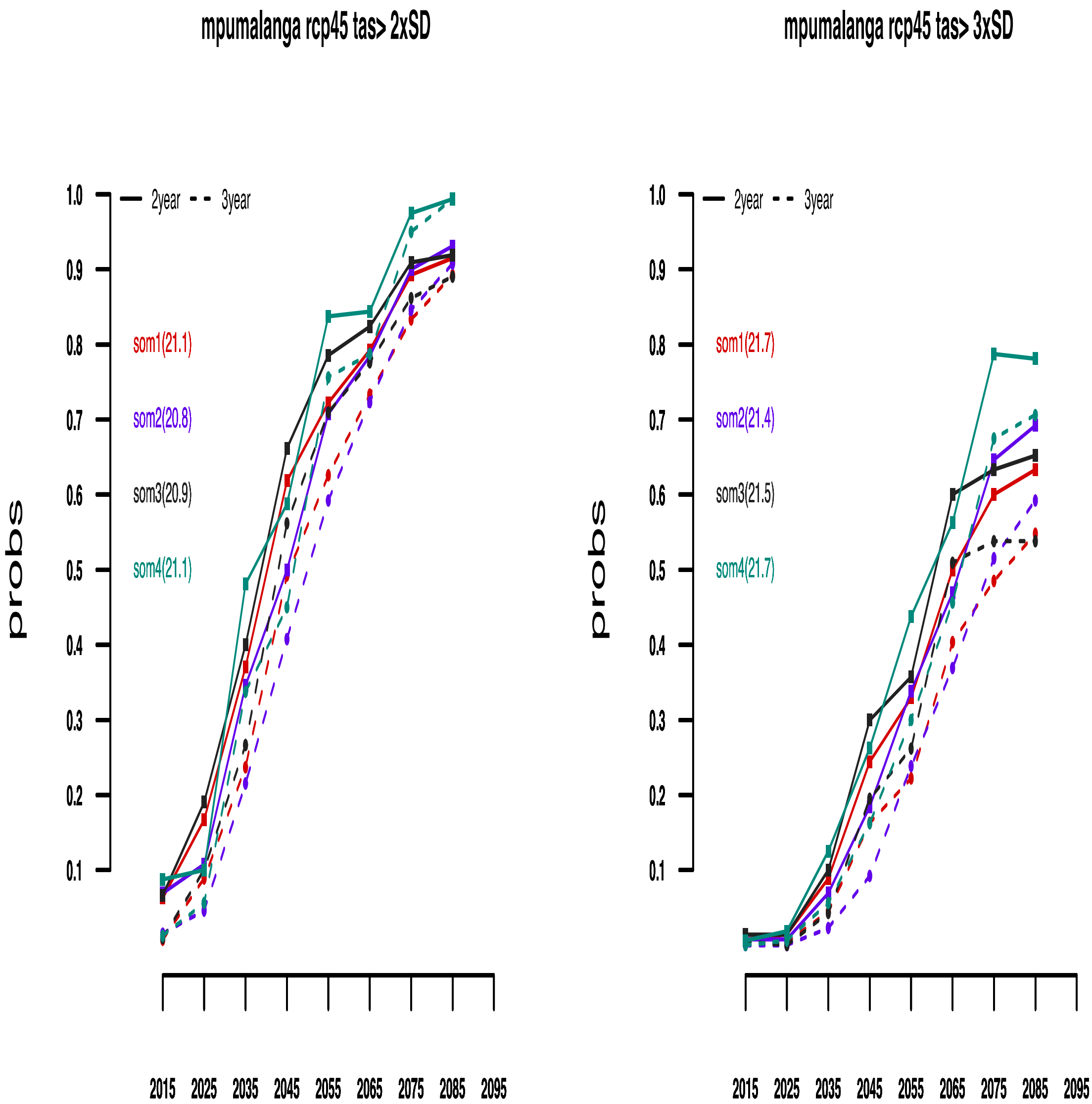


Figure MD7. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD6 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall

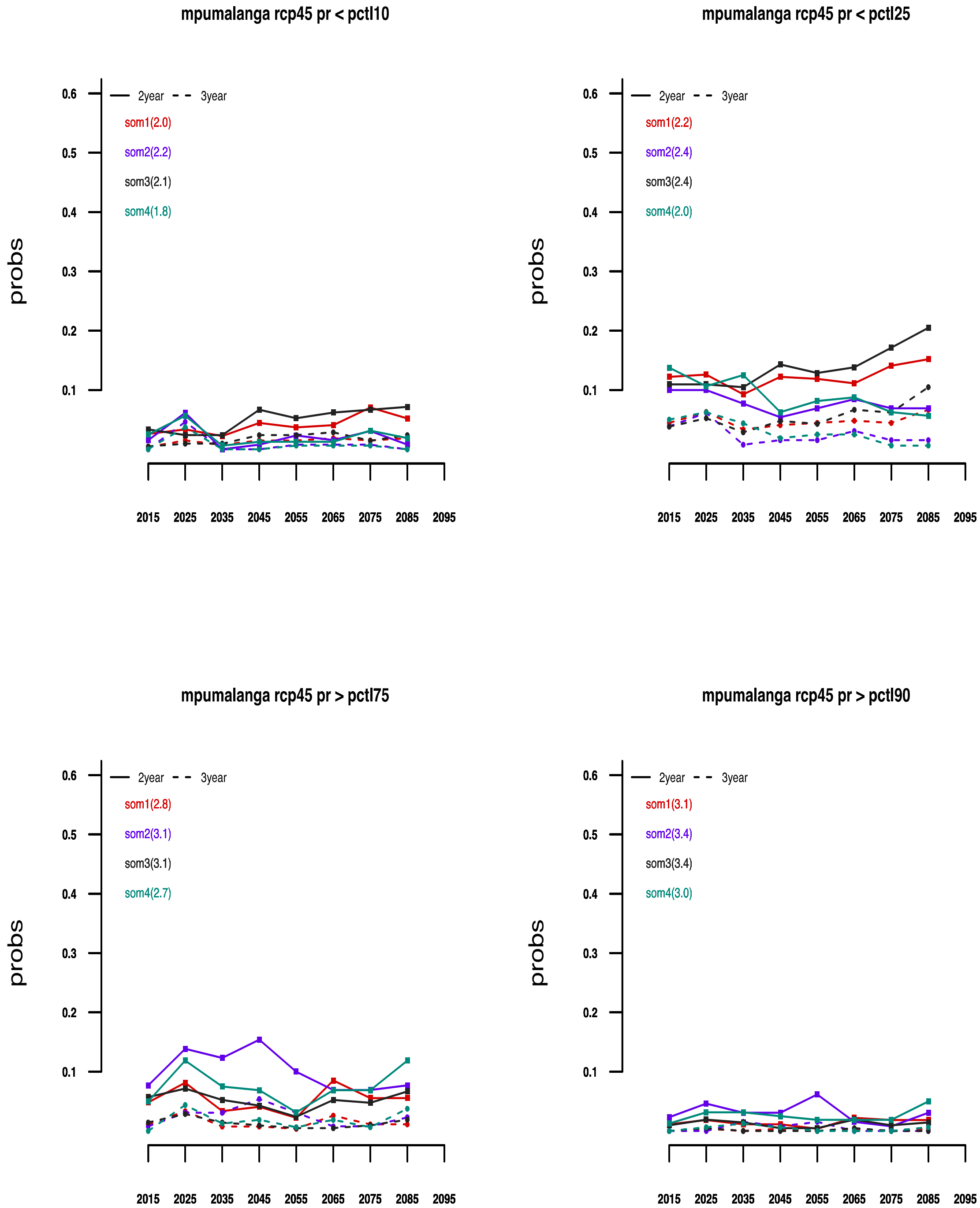


Figure MD8. Decadal probabilities that future annual rainfall totals will be below the 10^{th} percentile (top left) or the 25^{th} percentile (top right) or will exceed the 75^{th} percentile (bottom left) or the 90^{th} percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD6 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10^{th}, 25^{th}, 75^{th} or 90^{th} percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall less evaporation

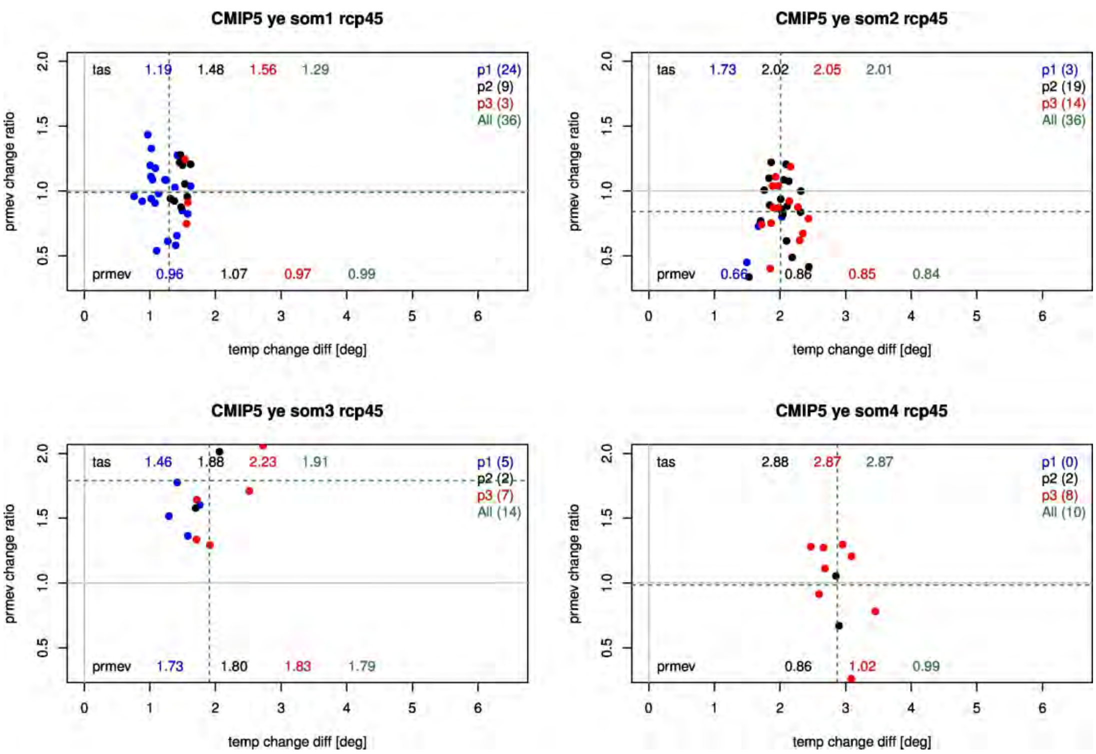


Figure MD9. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Mpumalanga Domain under RCP4.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 32 projections available in CMIP5 for RCP4.5.

Table MD4a. Scenarios for the year over the Mpumalanga Domain under RCP4.5 based on Figure MD9 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
85	1→2→4	1.25ºC/0.95	1.75ºC/0.90	2.25ºC/0.90
15	3	1.50ºC/1.75	2.00ºC/1.80	2.25ºC/1.85

Summary: Visually there is a relatively broad distribution of rainfall less evaporation values in most of these soms but the bulk of the projections points towards a decrease. A few projections join to give a relatively low likelihood alternate scenario of a substantial increase in rainfall less evaporation.

RCP4.5; temperature vs rainfall less evaporation

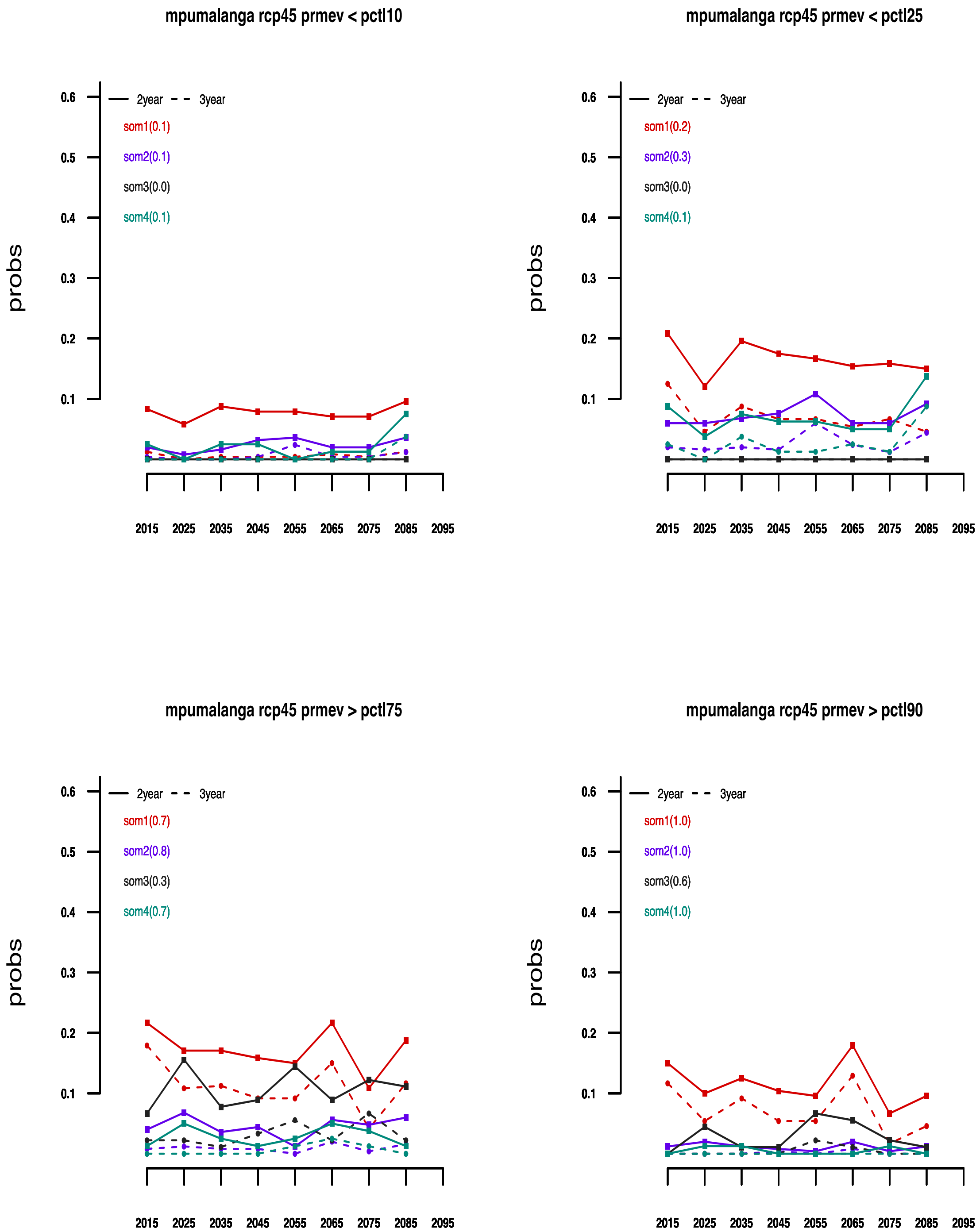


Figure MD10. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD9 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP6.0; temperature vs rainfall

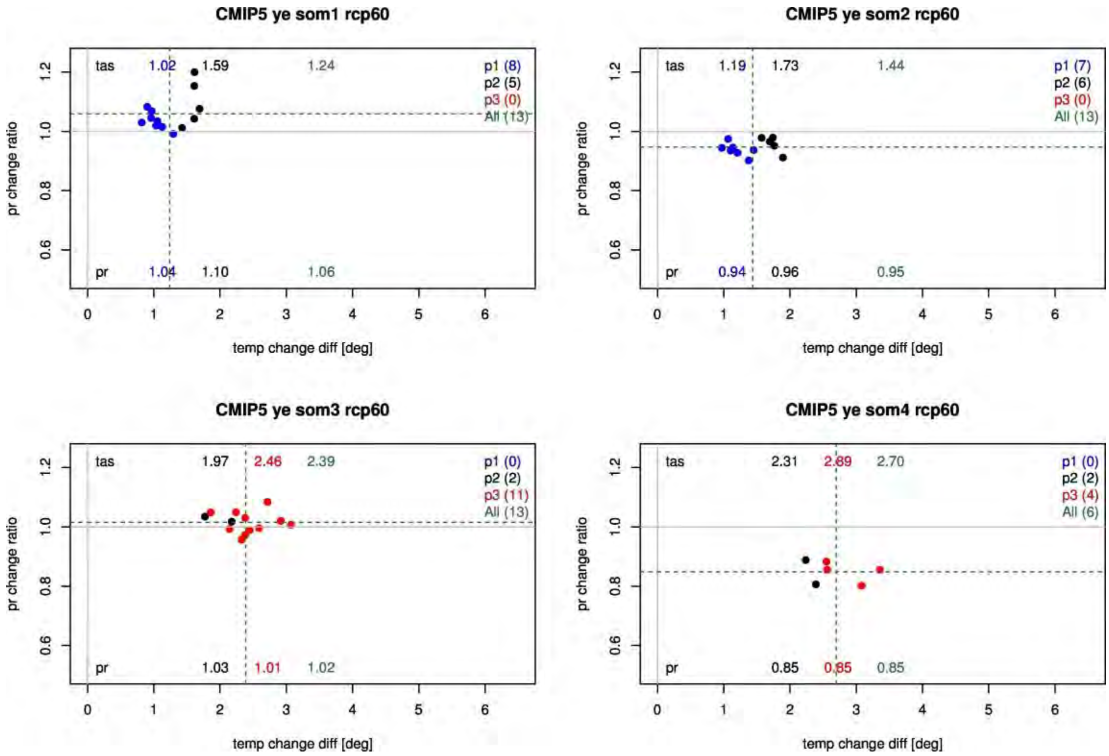


Figure MD11. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Mpumalanga Domain under RCP6.0 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 15 projections available in CMIP5 for RCP6.0.

Table MD5a. Scenarios for the year over the Mpumalanga Domain under RCP6.0 based on Figure MD11 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
60	1→3	1.00ºC/1.05	1.50ºC/1.10	2.50ºC/1.00
40	2→4	1.25ºC/0.95	2.00ºC/0.90	3.00ºC/0.85

Summary: Highest likelihood for an increase, or at least little change, in rainfall, with a decrease in the alternate warmer scenario.

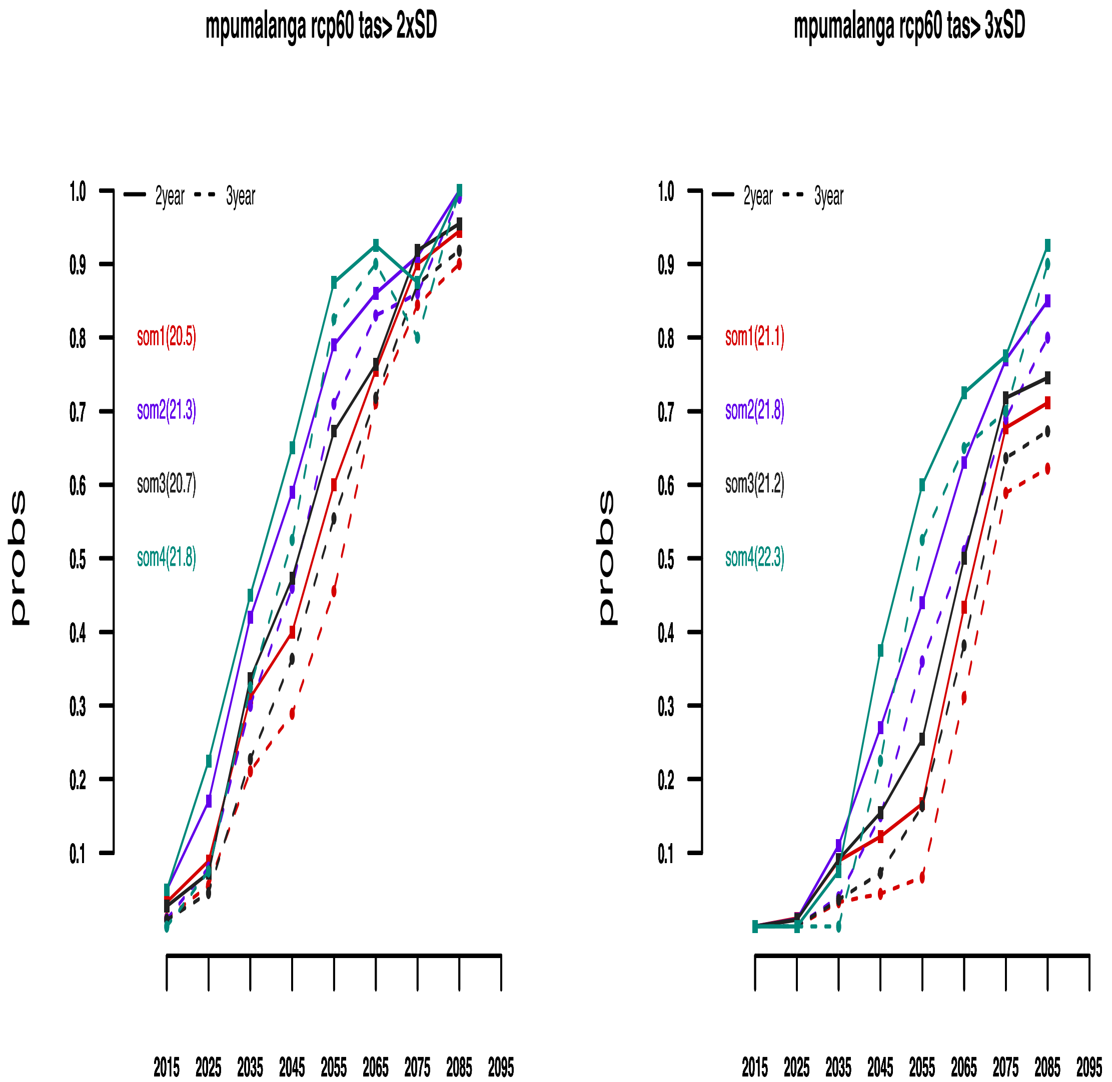


Figure MD12. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD11 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP6.0; temperature vs rainfall

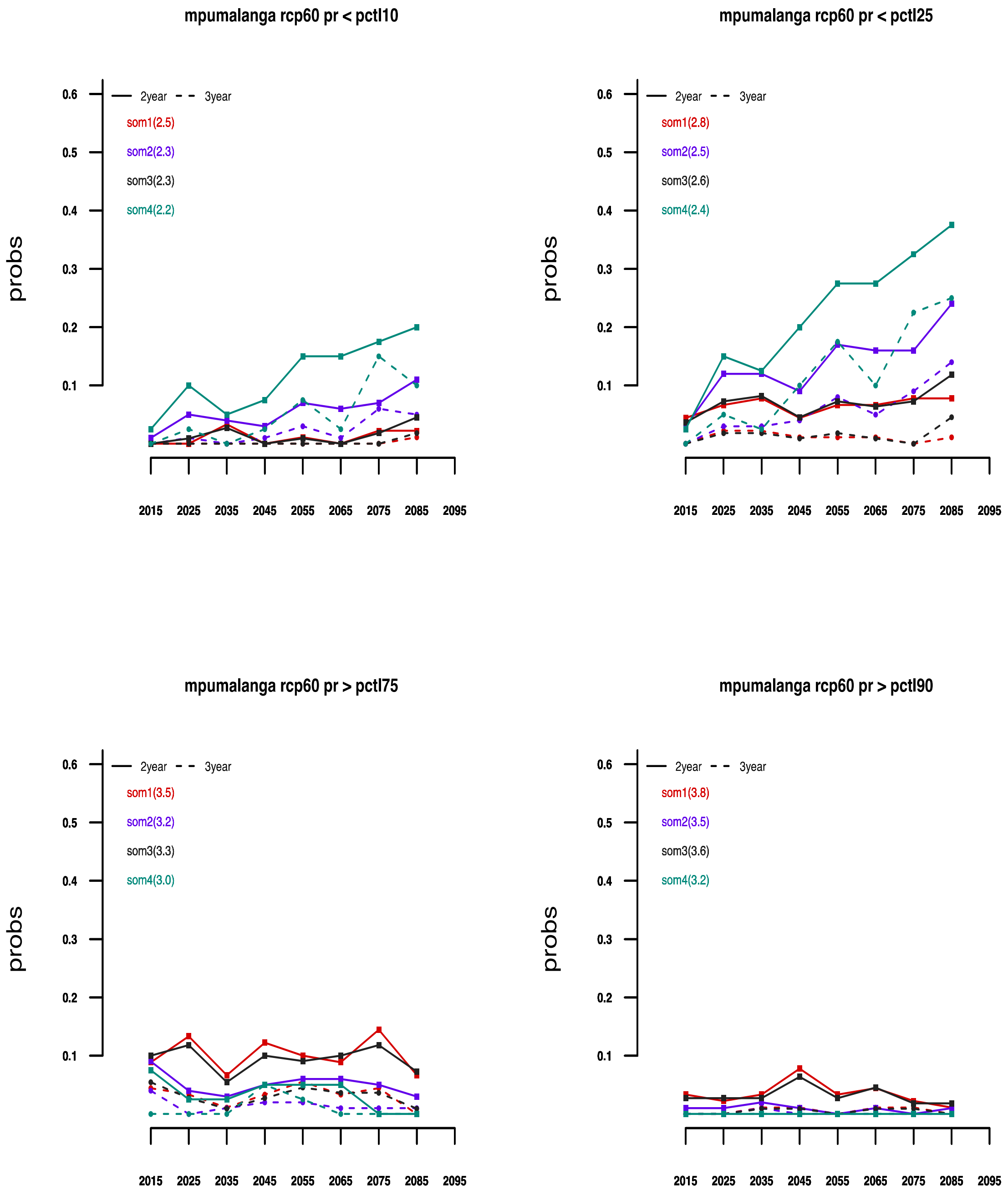


Figure MD13. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD11 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP6.0; temperature vs rainfall less evaporation

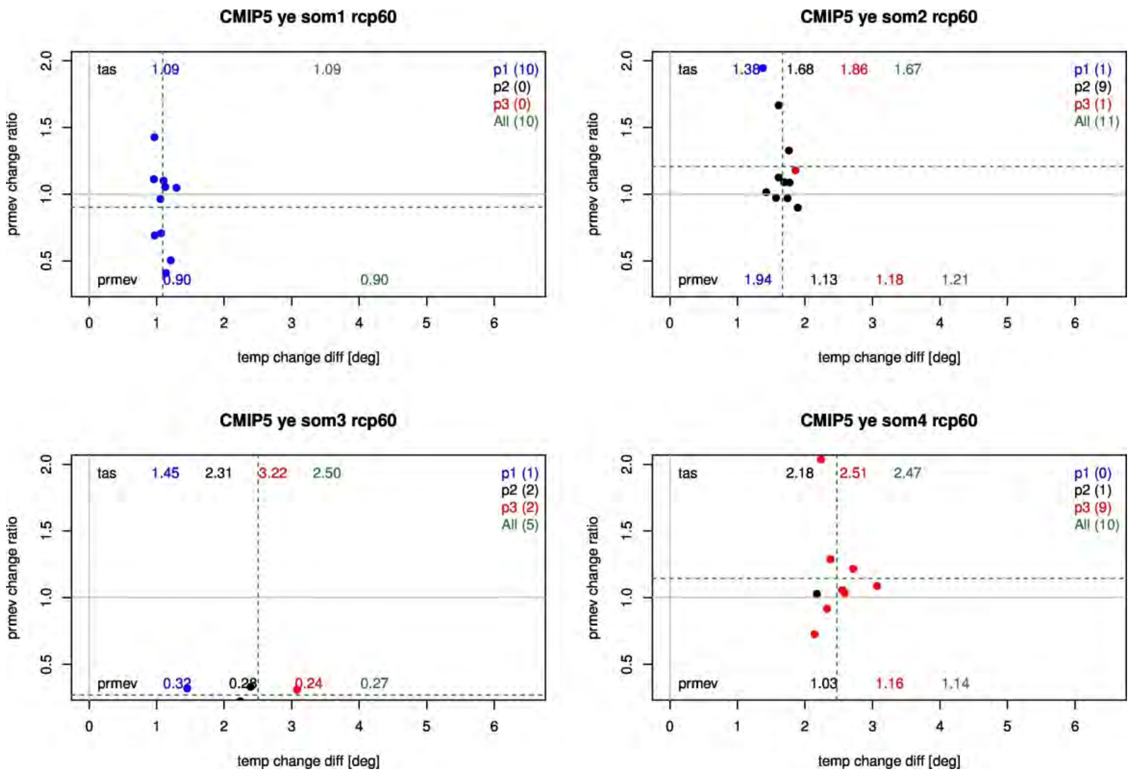


Figure MD14. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Mpumalanga Domain under RCP6.0; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 12 projections in CMIP5 for RCP6.0.

Table MD6a. Scenarios for the year over the Mpumalanga Domain under RCP6.0 based on Figure MD14 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
85	1→2→4	1.00ºC/0.95	1.75ºC/1.05	2.50ºC/1.15
15	3	1.50ºC/0.30	2.25ºC/0.30	3.25ºC/0.30

Summary: With the limited number of projections available these results need to be treated with caution. Visually there may be a mixture of increased and reduced rainfall less evaporation. Nevertheless the weight appears to be towards an increase notwithstanding the small of outlying projections in som3.

RCP6.0; temperature vs rainfall less evaporation

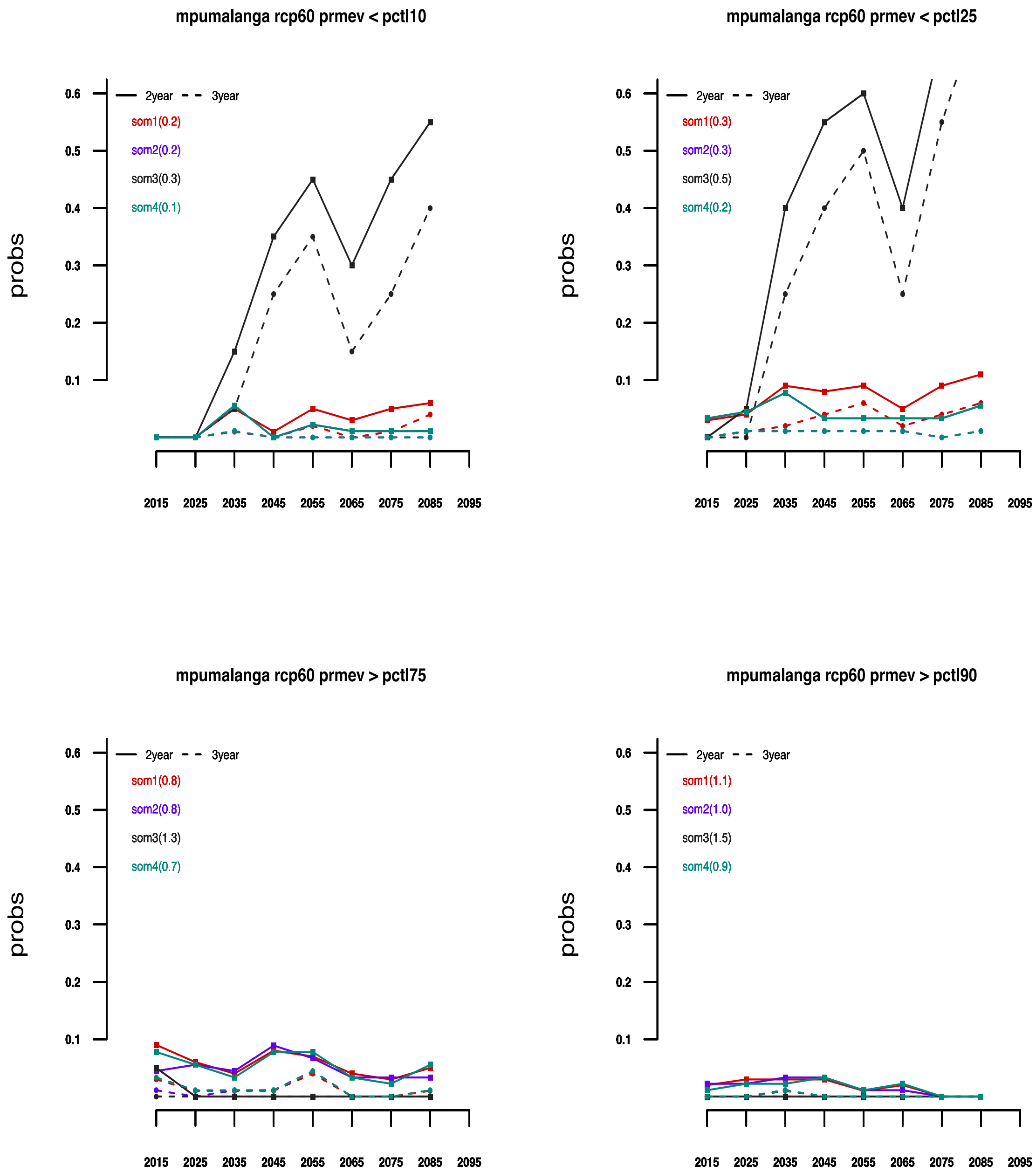


Figure MD127. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD14 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

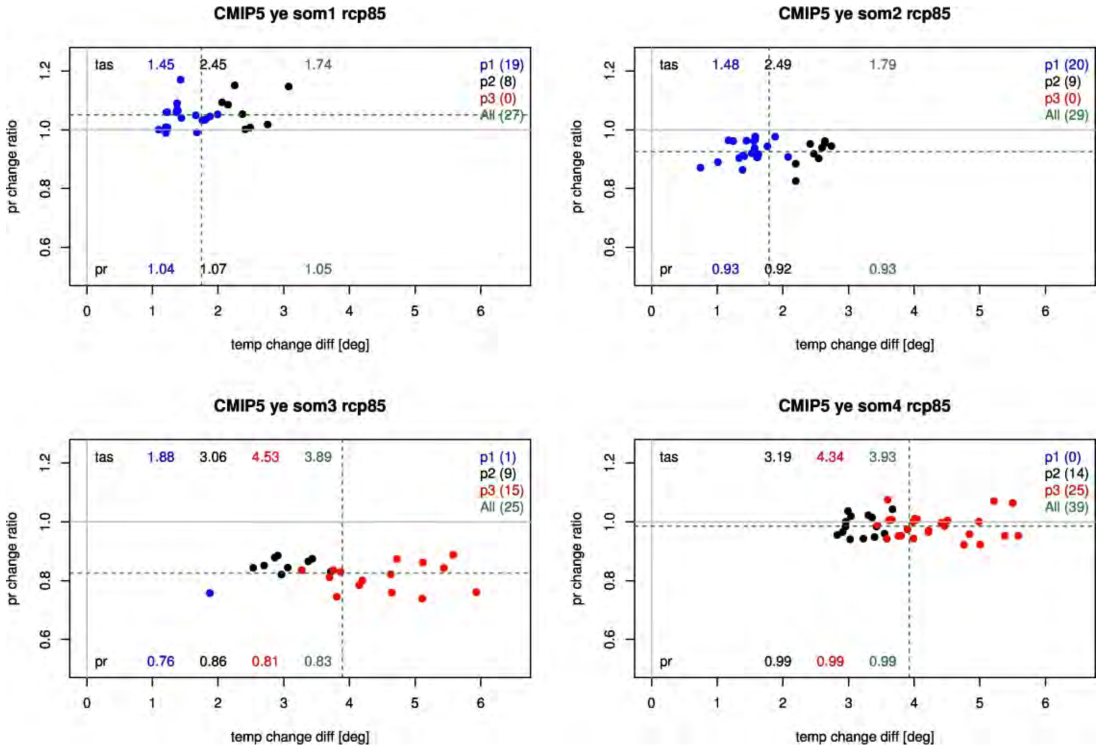


Figure MD16. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Mpumalanga Domain under RCP8.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 40 projections available in CMIP5 for RCP8.5.

Table MD7a. Scenarios for the year over the Mpumalanga Domain under RCP8.5 based on Figure MD16 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
55	1→4	1.50ºC/1.05	3.00ºC/1.00	4.25ºC/1.00
45	2→3	1.50ºC/0.95	2.75ºC/0.90	4.50ºC/0.80

Summary: Two scenarios with almost similar likelihoods, one with little change in rainfall, the other leading to steady decrease in time.

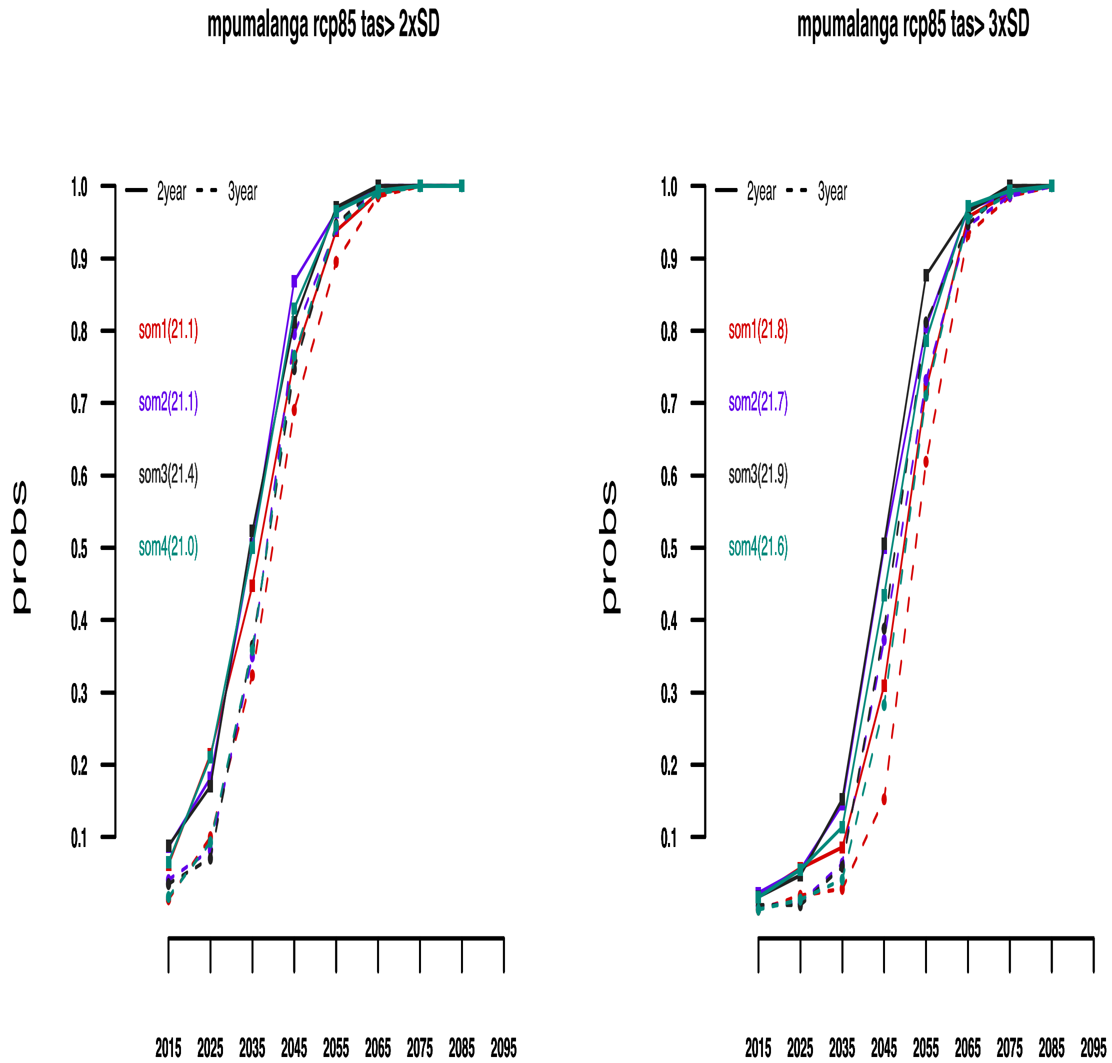


Figure MD17. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD16 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

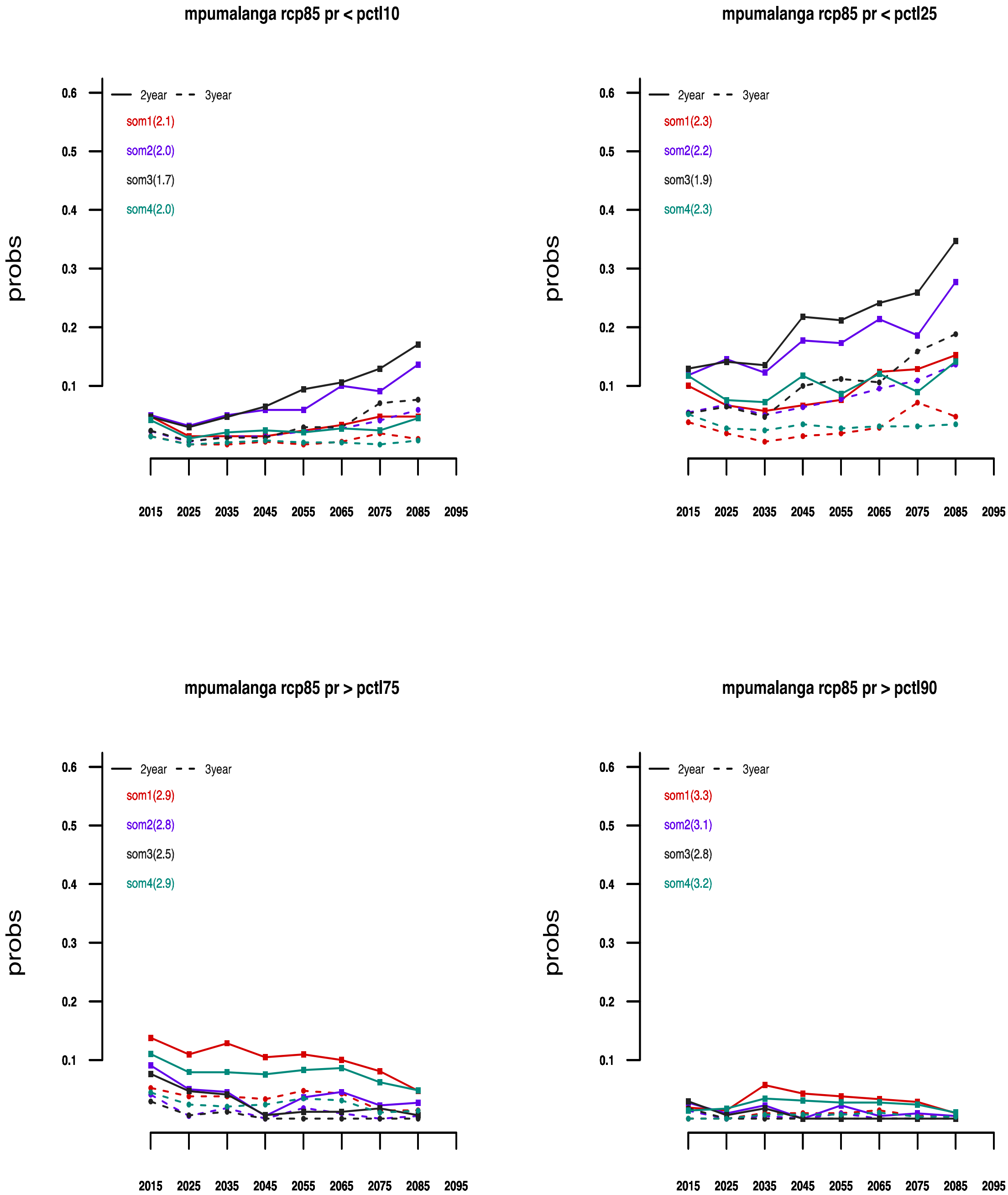


Figure MD18. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD16 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

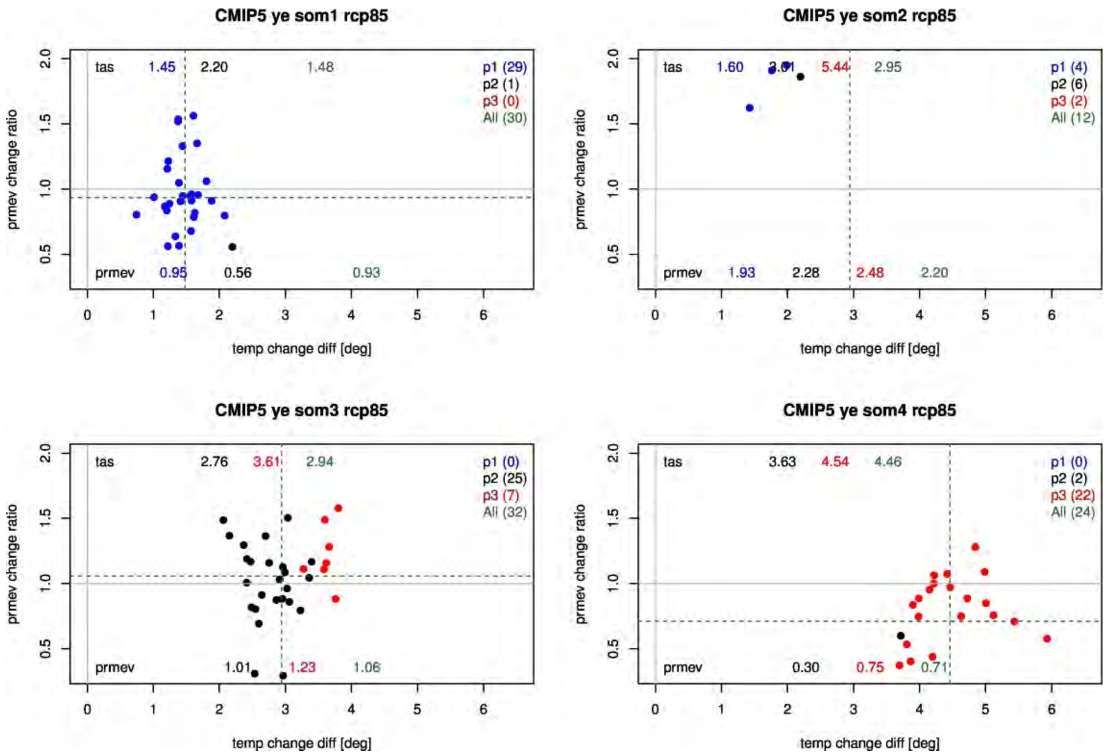


Figure MD19. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Mpumalanga Domain under RCP8.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 32 projections in CMIP5 for RCP8.5.

Table MD8a. Scenarios for the year over the Mpumalanga Domain under RCP8.5 based on Figure MD19 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
85	1→3→4	1.50ºC/0.95	2.75ºC/1.00	4.50ºC/0.85
15	2	1.50ºC/1.90	3.00ºC/2.25	5.50ºC/2.50

Summary: Despite the substantial number of projections available this analysis appears to separate into a predominately drier scenario together with a low-likelihood wetter scenario (som2) formed by a small number of outlying projections.

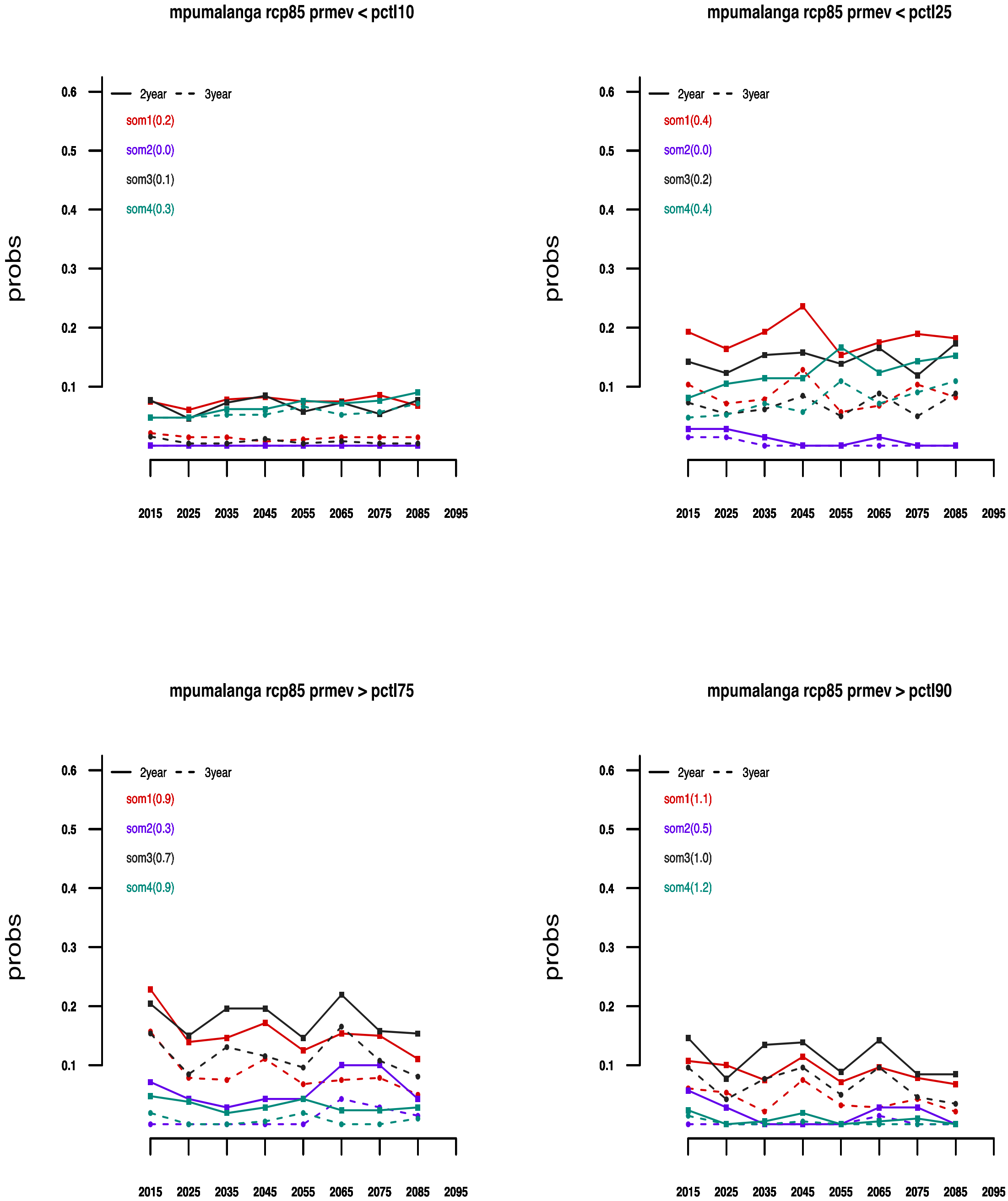


Figure MD20. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure MD19 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

Self-Organising Maps Results for the Changane Domain

Introduction. Results are presented below for the analyses through self-organising maps (soms) for the Changane Domain. Assessments of soms analyses for each RCP and temperature vs rainfall or temperature vs rainfall less evaporation are presented individually towards the end of this document; RCPs start at 2.6 and increase successively, temperature vs rainfall is presented before temperature vs rainfall less evaporation. Results from the soms are charted on each page followed by a table giving suggested scenarios from these particular results; a brief justification for the suggested scenarios is provided below each table.

Immediately following this introductory section is a collation of the results from the soms tables for easy reference. Below the collated table for each RCP is a further table giving, for each individual soms analysis, two suggested extreme scenarios, derived entirely subjectively. These extreme scenarios focus on changes to rainfall or to rainfall less evaporation as appropriate, and are an attempt to indicate possible scenarios representing greatest reasonable increases or decreases in rainfall or in rainfall less evaporation for that particular RCP. Note that had the focus been towards relatively high/low temperature increases different extreme scenarios would have been produced on at least some occasions. Thus the suggested extreme scenarios do not capture necessarily greatest and least changes in temperature projected for that RCP.

The number of projections for a given RCP, listed in the soms charts captions and repeated in the collation tables, may differ between the temperature against rainfall alone analyses and the temperature against rainfall less evaporation analyses for technical reasons.

Also provided following the tables of recommended scenarios for each RCP overall, and towards the end of this document for individual soms under each RCP, are results for the inter-annual variability (IAV) calculations. These illustrate future decadal probabilities that in successive two- and three-year periods:

- annual temperatures will exceed +2 and +3 standard deviations
- annual rainfall totals or rainfall less evaporation values will be below the 10th and 25th percentiles
- annual rainfall totals or rainfall less evaporation values will be above the 75th and 90th percentiles

relative to values across the base period of 1979-2005. Temperature probabilities have been presented only for the temperature vs rainfall soms as those for the temperature vs rainfall less evaporation soms are equivalent. Details of these charts are discussed further in the main document. Equivalent charts of IAV calculations for each RCP in total are provided immediately following the summary tables and before details of individual RCPs.

Summary of results.

Temperature against rainfall. As might be expected, temperatures in the RCP scenarios increase with emissions, a rise that is, in general, greater for the drier scenarios. Rainfall changes in both directions appear in all suggested scenarios for individual RCPs, although the higher likelihoods in general are for decreased rainfall in all RCPs.

Temperatures in the recommended extreme scenarios increase in general with RCP; rainfall changes in the increased scenarios tend to be projected to be above current levels, by no more than about 20%. Decreases of rainfall in the extreme scenarios are somewhat larger than the corresponding increases, typically 15-30%.

Likelihoods of annual temperatures exceeding two and three standard deviations calculated across the base period of 1979-2005 increase, naturally, with RCP (see Figure CA), but vary also according to individual soms (see diagrams in the sections for the individual RCPs). Under RCP8.5 successive two and three year periods are almost certain by the 2070's for two standard deviations and by the 2080's for three standard deviations. By contrast, under RCP2.6 only one of the soms produces probabilities reaching almost 80% (by the 2050's) for two standard deviations whether over two or over three year periods, whereas for three standard deviations probabilities peak for just one som at around 50%. For RCP4.5 and RCP6.0 100% probabilities are reached only by the end of the century but for RCP8.5 all soms project 100% probabilities by the same times.

Likelihoods of annual rainfall totals outside the 10th and 90th percentiles over 2 and 3 years increase/decrease slightly respectively with high RCPs, in general being below 10% (see Figure CB). Similar increasing/decreasing trends of these likelihoods in time are in general apparent for all individual RCPs also, but there is also distinct differences in likelihoods for individual soms (see diagrams in the sections for the individual RCPs). For many soms likelihoods remain below 10% throughout but for certain ones these may rise towards 30% or higher. The results suggest future increased spread of rainfall distributions with more extended drier periods and reduced numbers of wetter periods.

Temperature against rainfall less evaporation. The picture is a little more complex for rainfall less evaporation, with drier conditions having the higher likelihoods throughout. In all cases some substantial increases in rainfall less evaporation are projected by some models, but in all cases these are with lower likelihood, i.e. they are projected by a small number of models that might be viewed as outliers to the main set of projections.

Temperatures in the suggested extreme scenarios increase in general with RCP. Marked decreases in water availability are suggested in the decreased extremes scenarios for all RCPs, with some large increases possible also in all RCPs.

Likelihoods of annual rainfall less evaporation amounts outside the 10th and 90th percentiles over 2 and 3 years, as similarly for rainfall totals, do not change substantially, in general being below 10% but perhaps are increased above this towards the end of the century for the higher RCPs (see Figure CC). However there are increasing/decreasing respectively likelihoods of 2/3 year values outside the 25th and 75th percentiles as the century proceeds, again especially for RCP6.0 and RCP8.5 (see Figures in individual sections). There does seem to be a slight weighting towards greater likelihoods for below the 25th percentile than for above the 75th, i.e. a skewing towards drier conditions. For many soms likelihoods in either direction remain below 10% throughout, but for some they may reach 30% or more.

Conclusions. In section 3 of the main report it was noted that the Changane Domain sits in western Mozambique on a plateau bound by mountain ranges at a location where ensemble means for all RCPs suggest future rainfall decreases on all time scales. One the contrary for rainfall less evaporation most ensemble means suggest that water availability will increase. Rainfall decreases have been given the higher likelihoods in all recommended scenarios, both for rainfall and for rainfall less evaporation. The reason is clear in the soms analyses, that the full sets of projections are skewed towards drier conditions such that the ensemble means are weighted against the substantial numbers of projections for relatively limited increases.

Across RCP2.6, RCP4.5 and RCP6.0 there is some consistency between suggested scenarios in terms of adjustments in rainfall and in rainfall less evaporation notwithstanding small increases in temperature with rising emissions. As found in most other areas for which the soms technique has been applied RCP8.5 stands out somewhat, both in terms of higher temperature increases as well as in adjustments to rainfall/rainfall less evaporation which tend to be more substantially negative, and additionally for rainfall less evaporation positive. Hence the recommendations below are weighted away from RCP8.5. Overall the recommendations suggest higher prospects of decreased over increased water availability according to both analyses. However, decreases in water availability according to the rainfall less evaporation assessments might be more significant than under the rainfall alone assessments, as the former take into consideration increased evaporation as temperatures rise.

If there is a requirement to examine projected changes under RCP8.5 then use the recommended and extreme scenarios repeated from the appropriate collated tables below.

The IAV calculations indicate steady increases in time in likelihoods of extended 2- and 3-year spells of temperatures above historical annual 2 and 3 standard deviations, greater with higher RCPs and reaching 100% in many cases towards the end of the century. Both for rainfall and for rainfall less evaporation likelihoods of extended 2- and 3-years spells below and above historical annual 10th and 90th percentiles do not change significantly in time, but those for the 25th and 90th percentiles do (although not for all soms), suggesting an increase in spread of annual values with possible slight bias towards drier conditions.

Recommended Scenarios for the Changane Domain based on RCP2.6, RCP4.5 and RCP6.0

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
60	1.25ºC/0.95	1.50ºC/0.90	2.00ºC/0.90
40	1.00ºC/1.10	1.50ºC/1.05	2.00ºC/1.10

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall changes)

	2040	2065	2080
Increased	1.00ºC/1.20	1.50ºC/1.15	2.00ºC/1.20
Decreased	1.25ºC/0.85	2.00ºC/0.85	2.50ºC/0.80

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
70	1.25ºC/0.80	1.75ºC/0.80	2.00ºC/0.85
30	1.00ºC/1.50	1.50ºC/1.50	1.75ºC/1.75

Extreme scenarios based on temperature against rainfall less evaporation analyses (focussed primarily on rainfall less evaporation changes)

	2040	2065	2080
Increased	1.00ºC/1.40	1.75ºC/1.50	2.00ºC/1.70
Decreased	1.25ºC/0.50	1.75ºC/0.60	2.25ºC/0.50

Recommended Scenarios for the Changane Domain based on RCP8.5

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
45	1.50ºC/0.95	2.75ºC/0.95	4.25ºC/0.95
40	1.50ºC/0.95	2.50ºC/0.90	4.25ºC/0.80
15	1.50ºC/1.10	2.50ºC/1.10	3.50ºC/1.05

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall changes)

	2040	2065	2080
Increased	1.75ºC/1.15	2.75ºC/1.15	4.00ºC/1.10
Decreased	1.75ºC/0.80	2.75ºC/0.75	4.25ºC/0.70

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
80	1.25ºC/0.90	2.50ºC/0.90	4.25ºC/0.80
20	1.50ºC/1.80	2.75ºC/1.90	4.25ºC/1.90

Extreme scenarios based on temperature against rainfall analyses (focussed primarily on rainfall less evaporation changes)

	2040	2065	2080
Increased	1.25ºC/1.80	2.75ºC/1.80	4.00ºC/1.80
Decreased	1.25ºC/0.50	2.50ºC/0.50	4.25ºC/0.50

Scenarios from each RCP for the Changane Domain based on analyses of temperature against rainfall to the left and on analyses of temperature against rainfall less evaporation to the right; in the summaries following each table TR refers to the temperature/rainfall table to the left and TRLE to the temperature/rainfall less evaporation table to the right. Following the RCP header are the numbers of projections available to produce TR and TRLE respectively. Note that the soms numbers in the second columns of each individual table are arbitrary and should not be used to inter-compare TR and TRLE.

RCP2.6 – 20 and 18 projections

	%		2040	2065	2080		%		2040	2065	2080
1	35	3	0.75ºC/1.00	1.00ºC/1.00	1.00ºC/1.00		45	1	1.00ºC/0.80	1.00ºC/0.85	1.00ºC/0.85
2	35	1	1.00ºC/0.95	1.00ºC/0.95	1.00ºC/0.90		25	3	0.75ºC/1.10	0.75ºC/1.20	0.75ºC/1.25
3	20	2	1.50ºC/0.95	1.75ºC/0.90	1.75ºC/0.85		20	2	1.50ºC/0.80	1.75ºC/0.70	1.75ºC/0.70
4	10	4	0.75ºC/1.20	0.75ºC/1.15	1.00ºC/1.15		10	4	0.75ºC/2.00	1.25ºC/2.00	1.25ºC/1.50

Summary: According to both the TR (Lines 2 and 3) and the TRLE (Lines 1 and 3) scenarios a decrease in water availability is perhaps the most likely future in this Domain.

Suggested extreme scenarios for RCP2.6 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	0.75ºC/1.20	1.00ºC/1.20	1.00ºC/1.20		1.00ºC/1.10	1.00ºC/1.50	1.50ºC/1.50
Decreased	1.25ºC/0.85	1.50ºC/0.85	1.75ºC/0.80		1.00ºC/0.50	1.00ºC/0.50	1.50ºC/0.60

RCP4.5 – 38 and 32 projections

	%		2040	2065	2080		%		2040	2065	2080
1	65	3→2	1.25ºC/0.95	1.75ºC/0.90	2.00ºC/0.90		90	3→2→4	1.25ºC/1.00	1.75ºC/0.85	2.00ºC/0.90
2	35	1→4	1.25ºC/1.05	1.75ºC/1.05	2.50ºC/1.05		10	1	1.25ºC/1.50	1.75ºC/1.80	2.00ºC/2.00

Summary: In both suggested scenarios there is a marked weighting towards a future decrease in available water resources.

Suggested extreme scenarios for RCP4.5 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.25ºC/1.10	1.50ºC/1.15	2.50ºC/1.15		1.00ºC/1.50	2.00ºC/1.50	2.00ºC/1.75
Decreased	1.25ºC/0.90	2.00ºC/0.85	2.25ºC/0.80		1.75ºC/0.50	1.75ºC/0.50	2.50ºC/0.50

RCP6.0 – 15 and 12 projections

	%		2040	2065	2080		%		2040	2065	2080
1	50	2→4	1.00ºC/0.95	1.75ºC/0.90	2.75ºC/0.85		55	3→4	1.00ºC/0.70	1.75ºC/0.70	2.50ºC/0.90
2	50	1→3	1.00ºC/1.10	1.75ºC/1.00	2.25ºC/1.00		45	1→2	1.00ºC/1.40	1.50ºC/1.20	2.00ºC/1.50

Summary: One of the more notable aspects of this to be taken into consideration is the relatively small number of projections available, which gives relatively less confidence in these results. In both cases there is a rough equality in likelihoods between increased and decreased water availability, with substantial changes in either direction suggested by the TRLE scenarios.

Suggested extreme scenarios for RCP6.0 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.00ºC/1.15	1.50ºC/1.15	2.00ºC/1.15		1.00ºC/1.50	1.50ºC/1.60	2.25ºC/1.70
Decreased	1.25ºC/0.85	2.25ºC/0.80	3.00ºC/0.80		1.00ºC/0.50	2.25ºC/0.50	3.00ºC/0.50

RCP8.5 – 40 and 32 projections

	%		2040	2065	2080		%		2040	2065	2080
1	45	2→4	1.50ºC/0.95	2.75ºC/0.95	4.25ºC/0.95		80	3→2→4	1.25ºC/0.90	2.50ºC/0.90	4.25ºC/0.80
2	40	2→3	1.50ºC/0.95	2.50ºC/0.90	4.25ºC/0.80		20	1	1.50ºC/1.80	2.75ºC/1.90	4.25ºC/1.90
3	15	1	1.50ºC/1.10	2.50ºC/1.10	3.50ºC/1.05						

Summary: In both scenarios the weight is distinctly towards future decreases in water availability.

Suggested extreme scenarios for RCP8.5 determined primarily in terms of changes in water availability – changes in water availability indicated appropriately by "increased" and "decreased" – no indication of relative likelihoods may be given – TR to left, TRLE to right

	2040	2065	2080		2040	2065	2080
Increased	1.75ºC/1.15	2.75ºC/1.15	4.00ºC/1.10		1.25ºC/1.80	2.75ºC/1.80	4.00ºC/1.80
Decreased	1.75ºC/0.80	2.75ºC/0.75	4.25ºC/0.70		1.25ºC/0.50	2.50ºC/0.50	4.25ºC/0.50

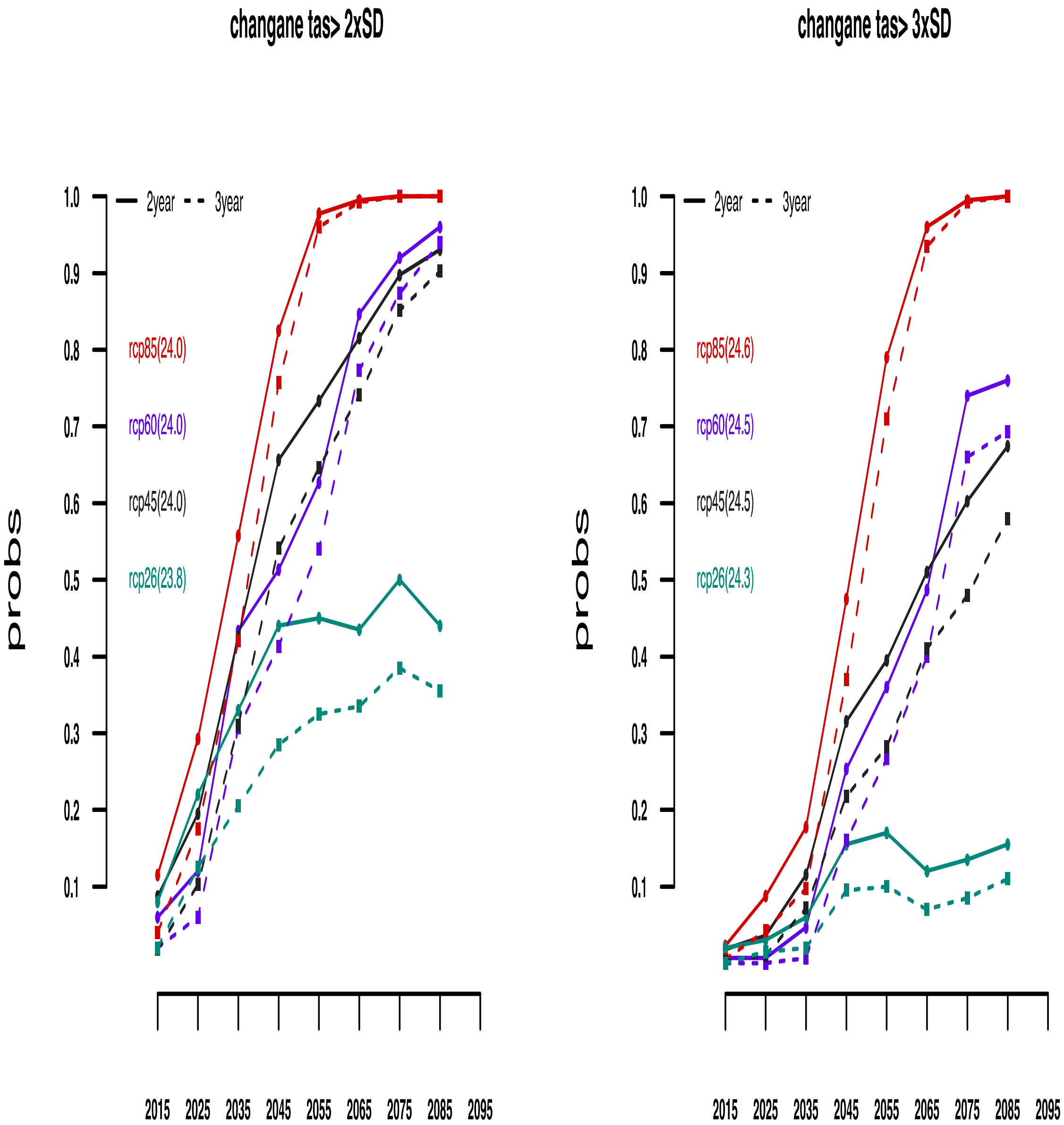


Figure CA. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes.

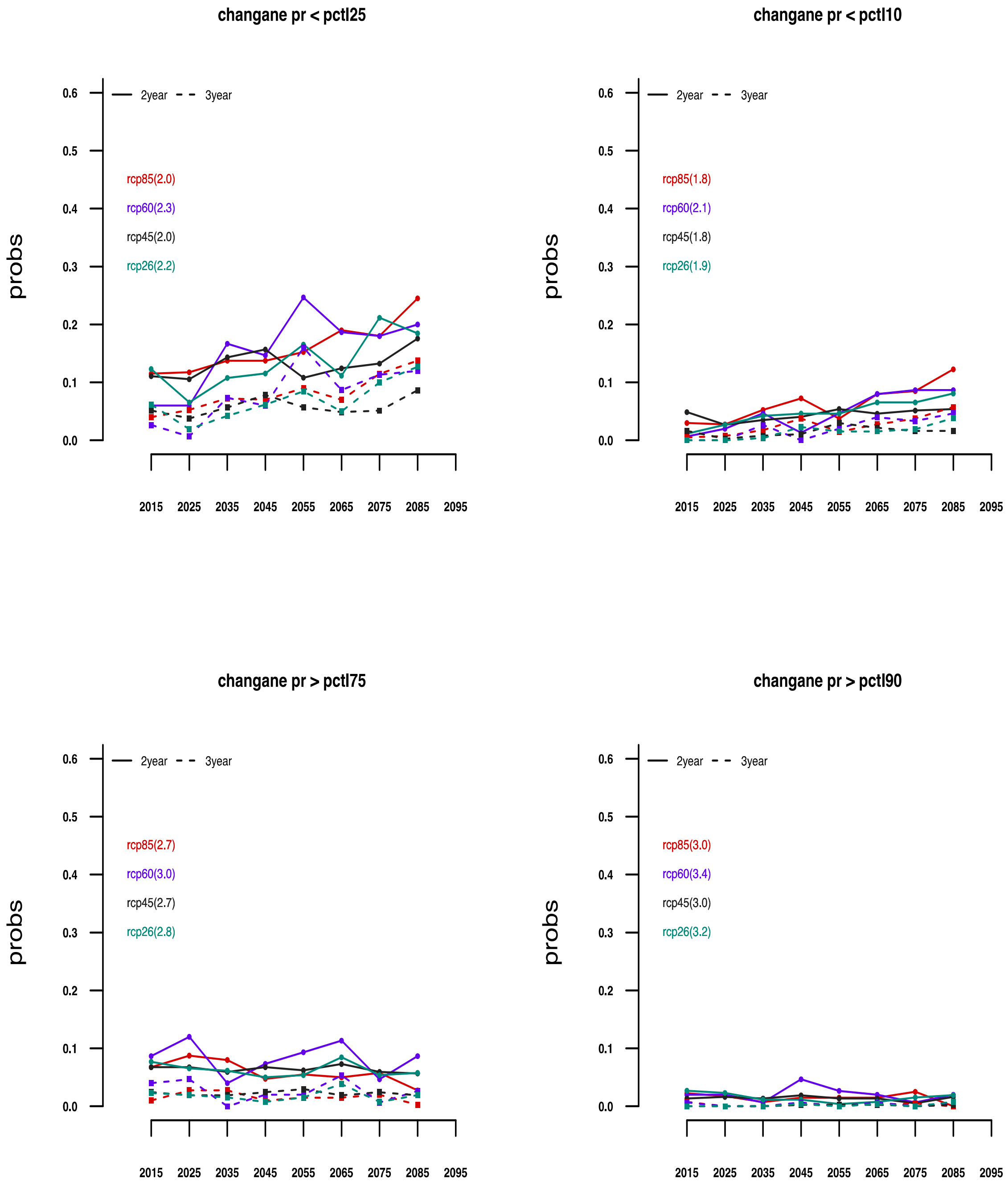


Figure CB. Decadal probabilities that future annual rainfall totals will be below the 25th percentile (top left) or the 10th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the RCP numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

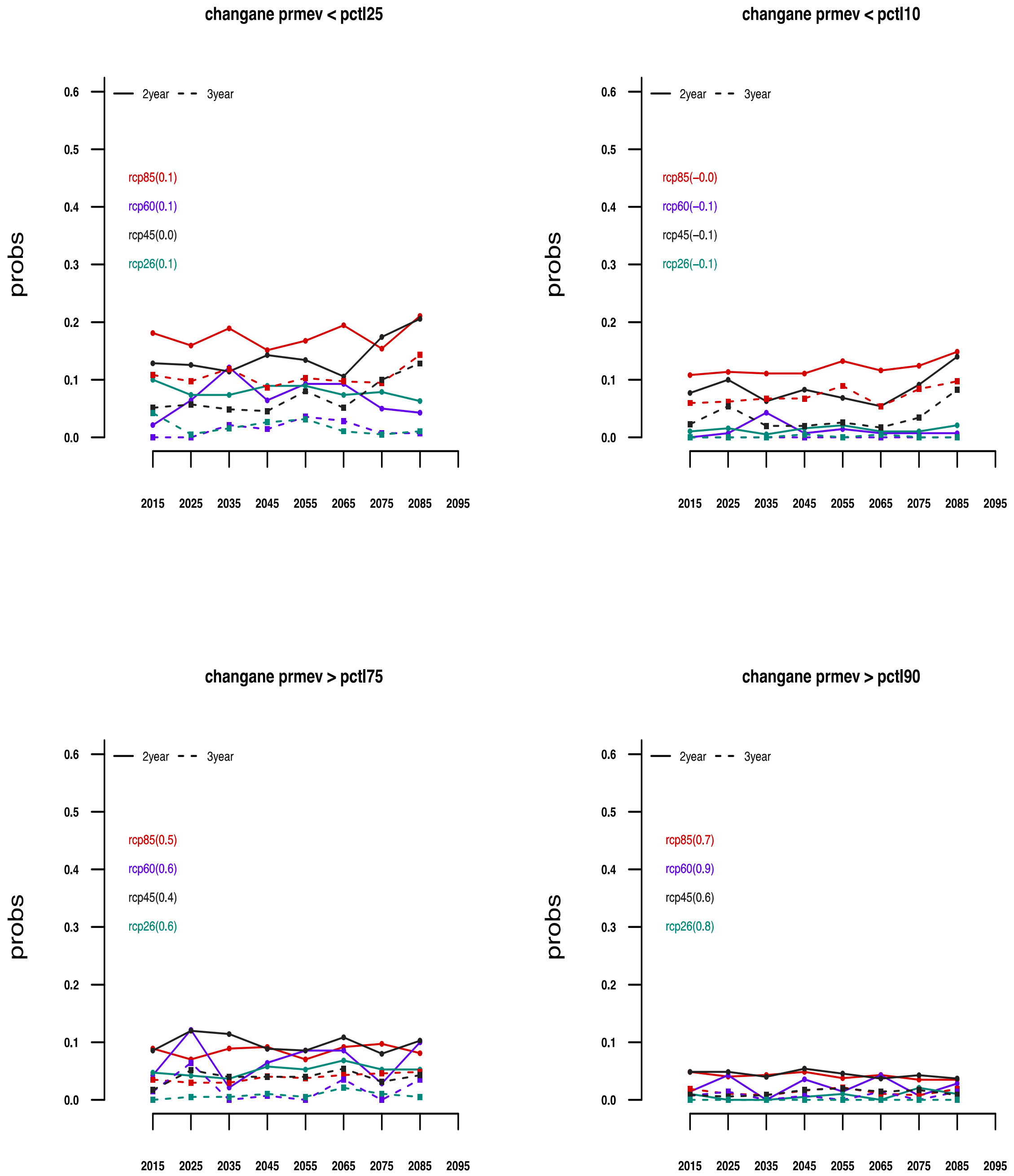


Figure CC. Decadal probabilities that future annual rainfall less evaporation totals will be below the 25th percentile (top left) or the 10th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different RCPs are shown in green (RCP2.6), black (RCP4.5), blue (RCP6.0) and red (RCP8.5) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the RCP numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP2.6; temperature vs rainfall

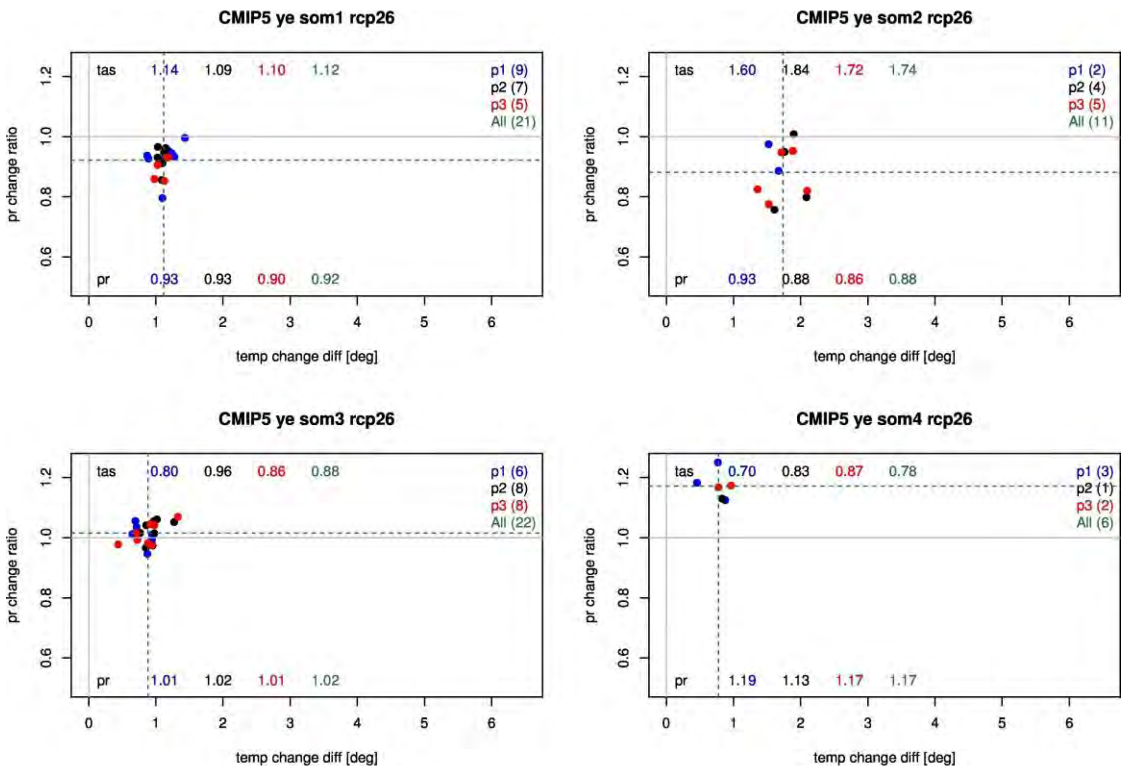


Figure CD1. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Changane Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 20 projections available in CMIP5 for RCP2.6.

Table CD1a. Scenarios for the year over the Changane Domain under RCP2.6 based on Figure CD1 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
35	3	0.75ºC/1.00	1.00ºC/1.00	1.00ºC/1.00
35	1	1.00ºC/0.95	1.00ºC/0.95	1.00ºC/0.90
20	2	1.50ºC/0.95	1.75ºC/0.90	1.75ºC/0.85
10	4	0.75ºC/1.20	0.75ºC/1.15	1.00ºC/1.15

Summary: Each som appears to form an individual pathway, with similar likelihoods in the top 2 soms. Overall the likelihood of no change in rainfall or of an increase is about 45% (soms 3 and 4), with a corresponding likelihood of 55% for a decrease (soms 1 and 2).

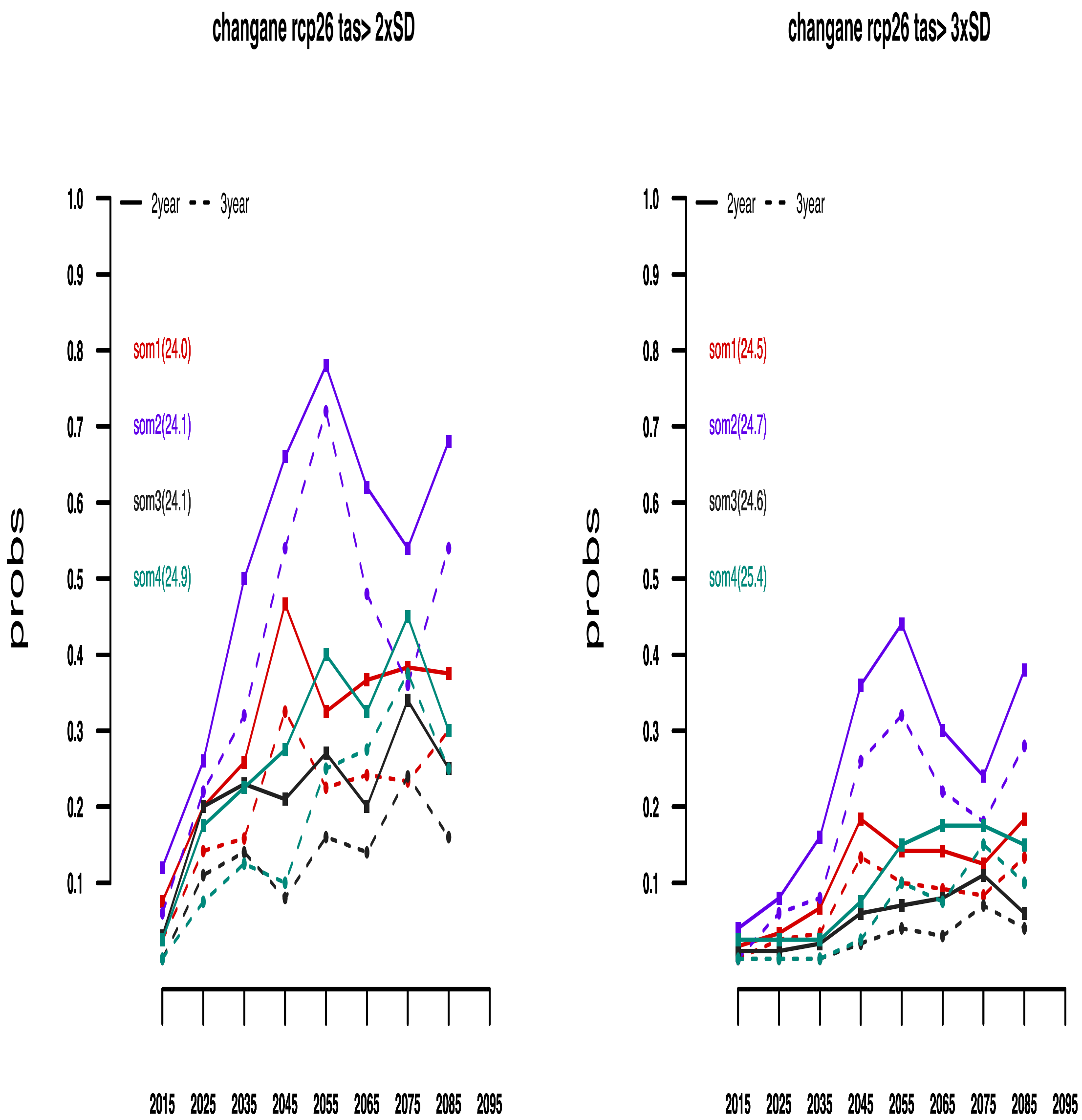


Figure CD28. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD1 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

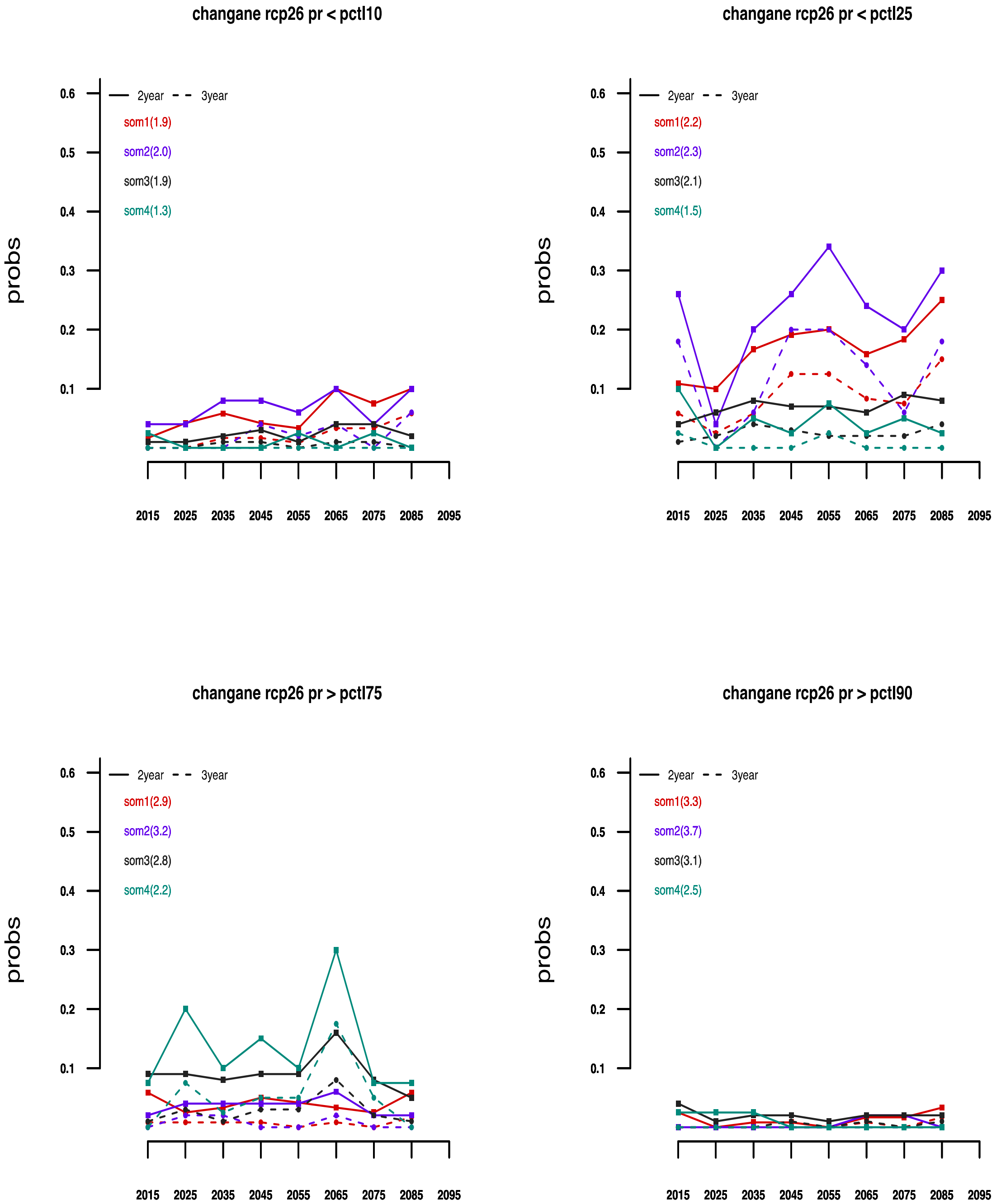


Figure CD29. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD1 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP2.6; temperature vs rainfall less evaporation

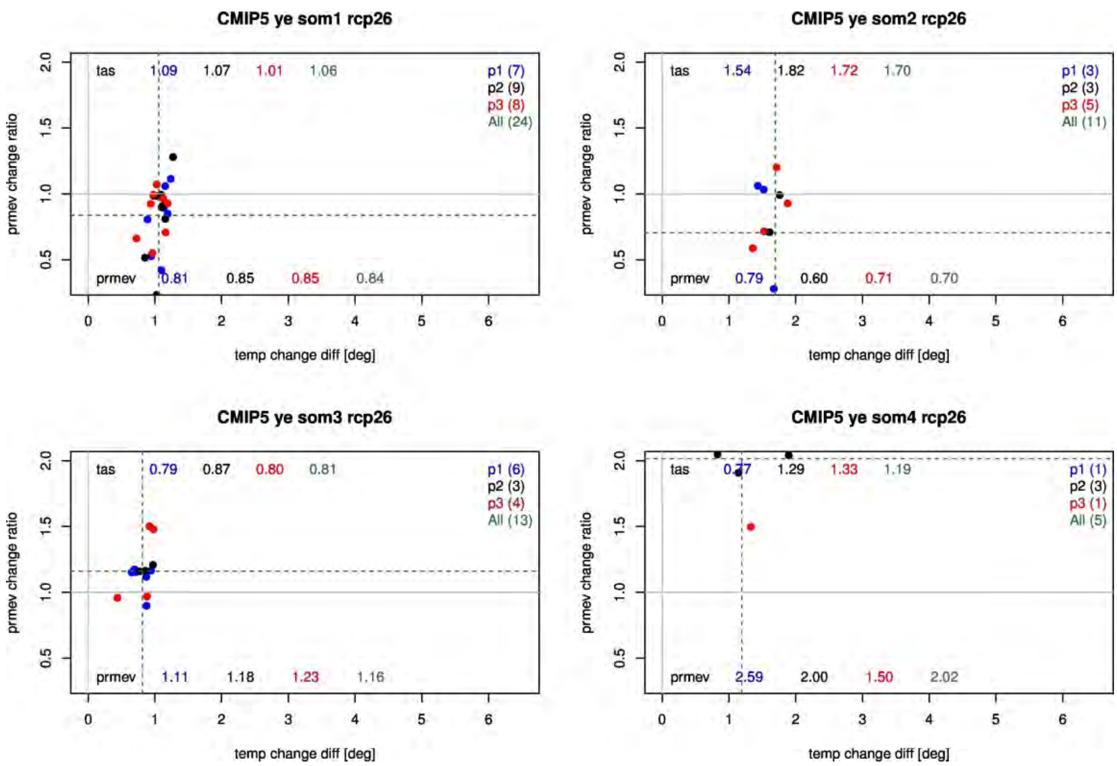


Figure CD4. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Changane Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 18 projections available in CMIP5 for RCP2.6.

Table CD2a. Scenarios for the year over the Changane Domain under RCP2.6 based on Figure CD4 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
45	1	1.00ºC/0.80	1.00ºC/0.85	1.00ºC/0.85
25	3	0.75ºC/1.10	0.75ºC/1.20	0.75ºC/1.25
20	2	1.50ºC/0.80	1.75ºC/0.70	1.75ºC/0.70
10	4	0.75ºC/2.00	1.25ºC/2.00	1.25ºC/1.50

Summary: Four scenarios with each som producing its own pathway. Overall a great likelihood of future decreased rainfall less evaporation (soms 1 and 2). The scenario represented in som4, with substantial increases in rainfall less evaporation, should be treated with caution because of the limited number of projections included.

RCP2.6; temperature vs rainfall less evaporation

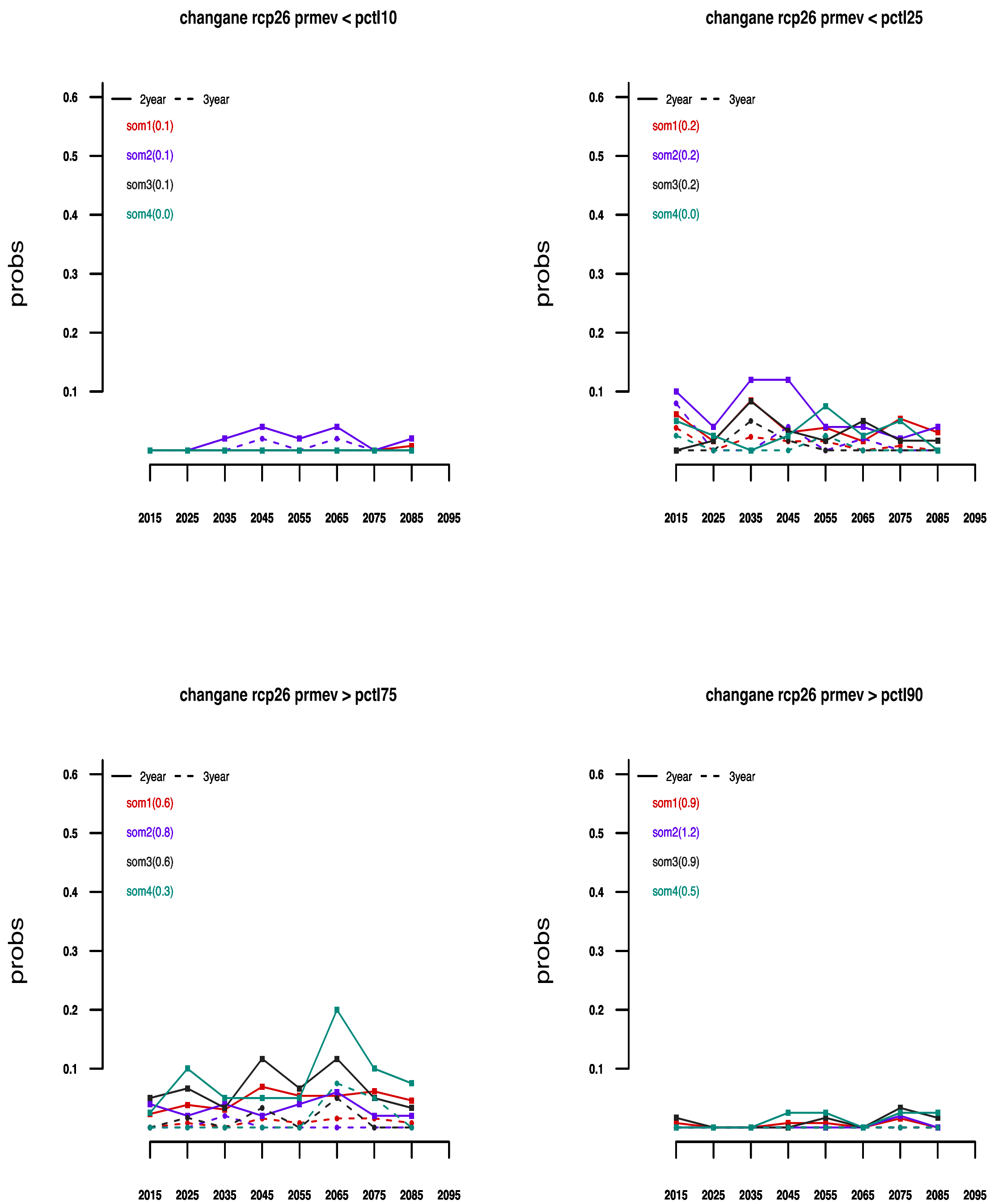


Figure CD30. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD3 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall

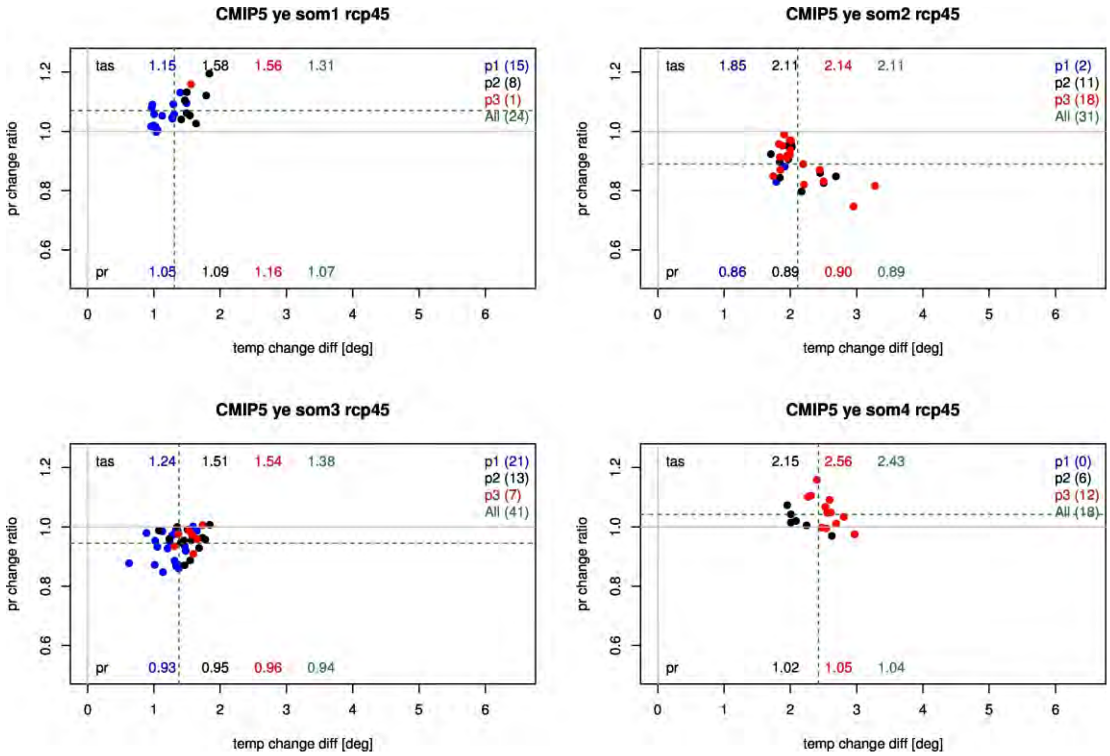


Figure CD6. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Changane Domain under RCP4.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 38 projections available in CMIP5 for RCP4.5.

Table CD3a. Scenarios for the year over the Changane Domain under RCP4.5 based on Figure CD6 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
65	3→2	1.25ºC/0.95	1.75ºC/0.90	2.00ºC/0.90
35	1→4	1.25ºC/1.05	1.75ºC/1.05	2.50ºC/1.05

Summary: Two scenarios, with the higher likelihood towards a decrease. In rainfall Note that this set is uncommon in that the warmer scenarios are those with increased rainfall.

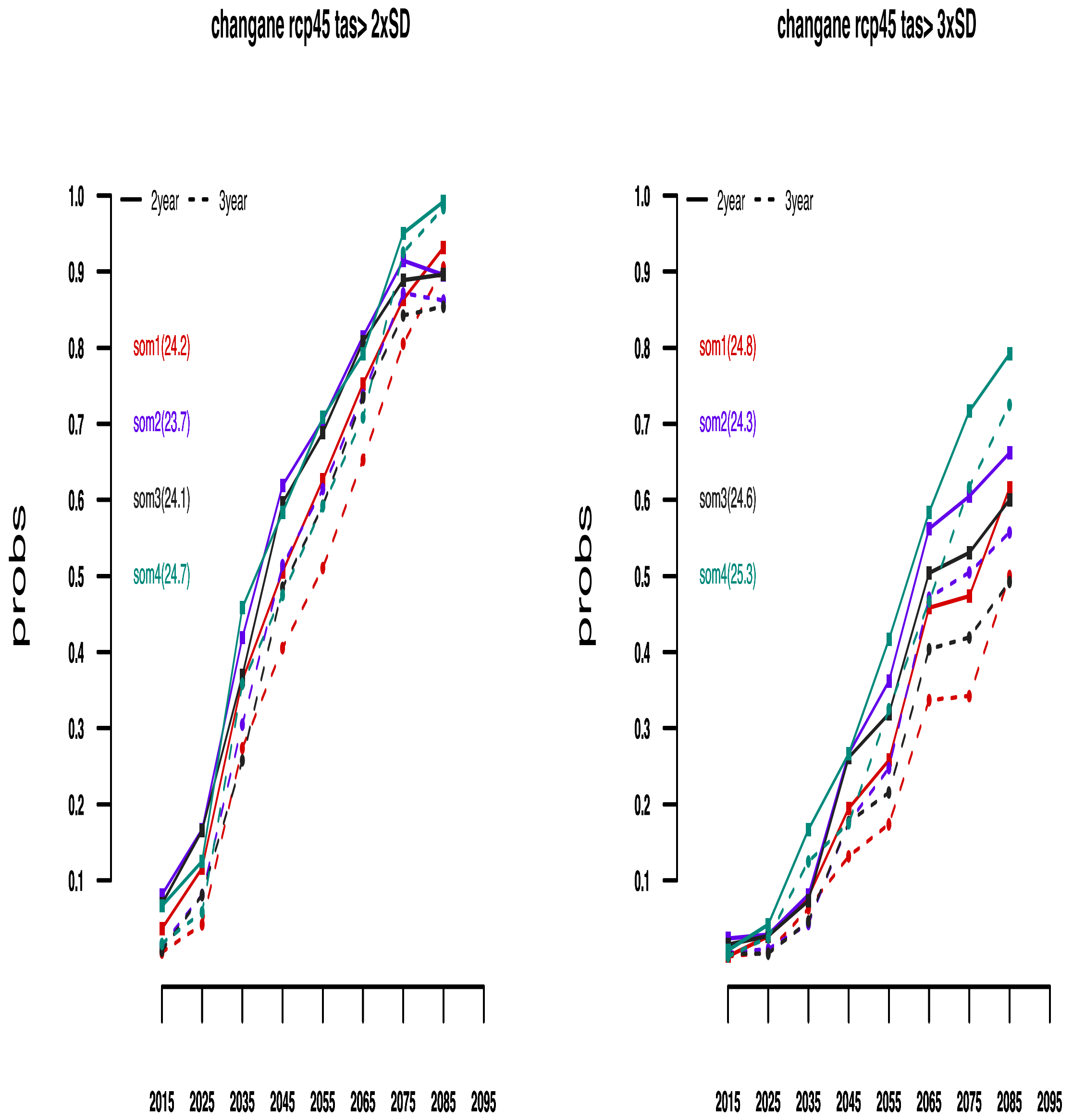


Figure CD7. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD6 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall

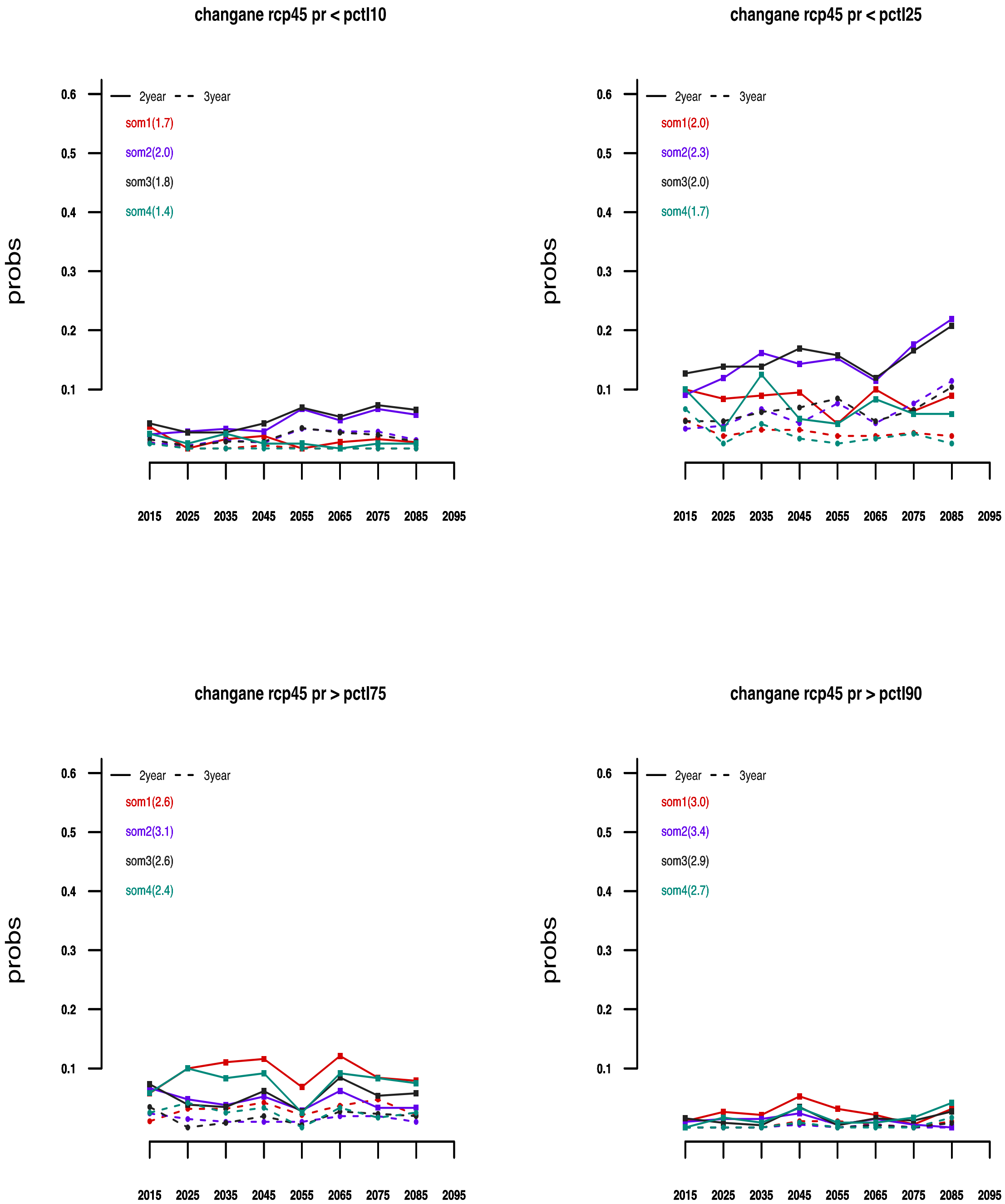


Figure CD8. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD6 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP4.5; temperature vs rainfall less evaporation

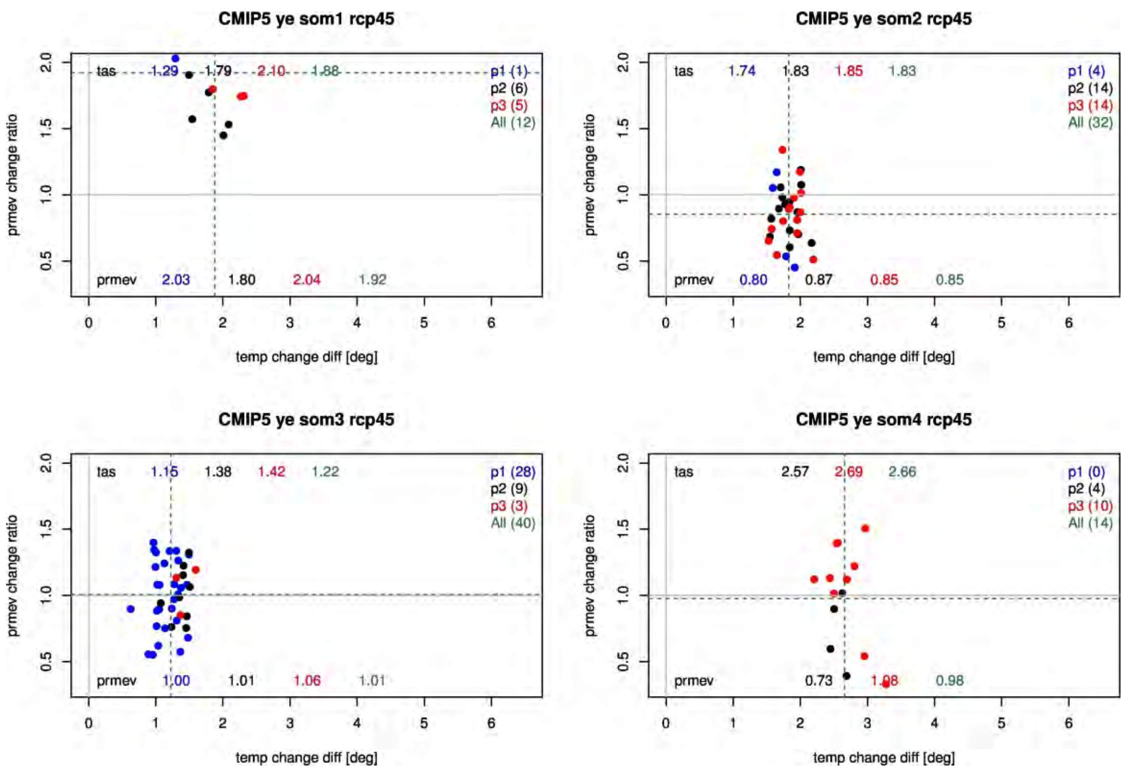


Figure CD9. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Changane Domain under RCP4.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 32 projections available in CMIP5 for RCP4.5.

Table CD4a. Scenarios for the year over the Changane Domain under RCP4.5 based on Figure CD9 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
90	3→2→4	1.25ºC/1.00	1.75ºC/0.85	2.00ºC/0.90
10	1	1.25ºC/1.50	1.75ºC/1.80	2.00ºC/2.00

Summary: Visually there is a relatively broad distribution of rainfall less evaporation values in most of these soms but the bulk of the projections points towards a decrease. A few projections join to give a relatively low likelihood alternate scenario (som1) of a substantial increase in rainfall less evaporation (which has been moderated in p1 using a few ‘wetter’ projections in som3).

RCP4.5; temperature vs rainfall less evaporation

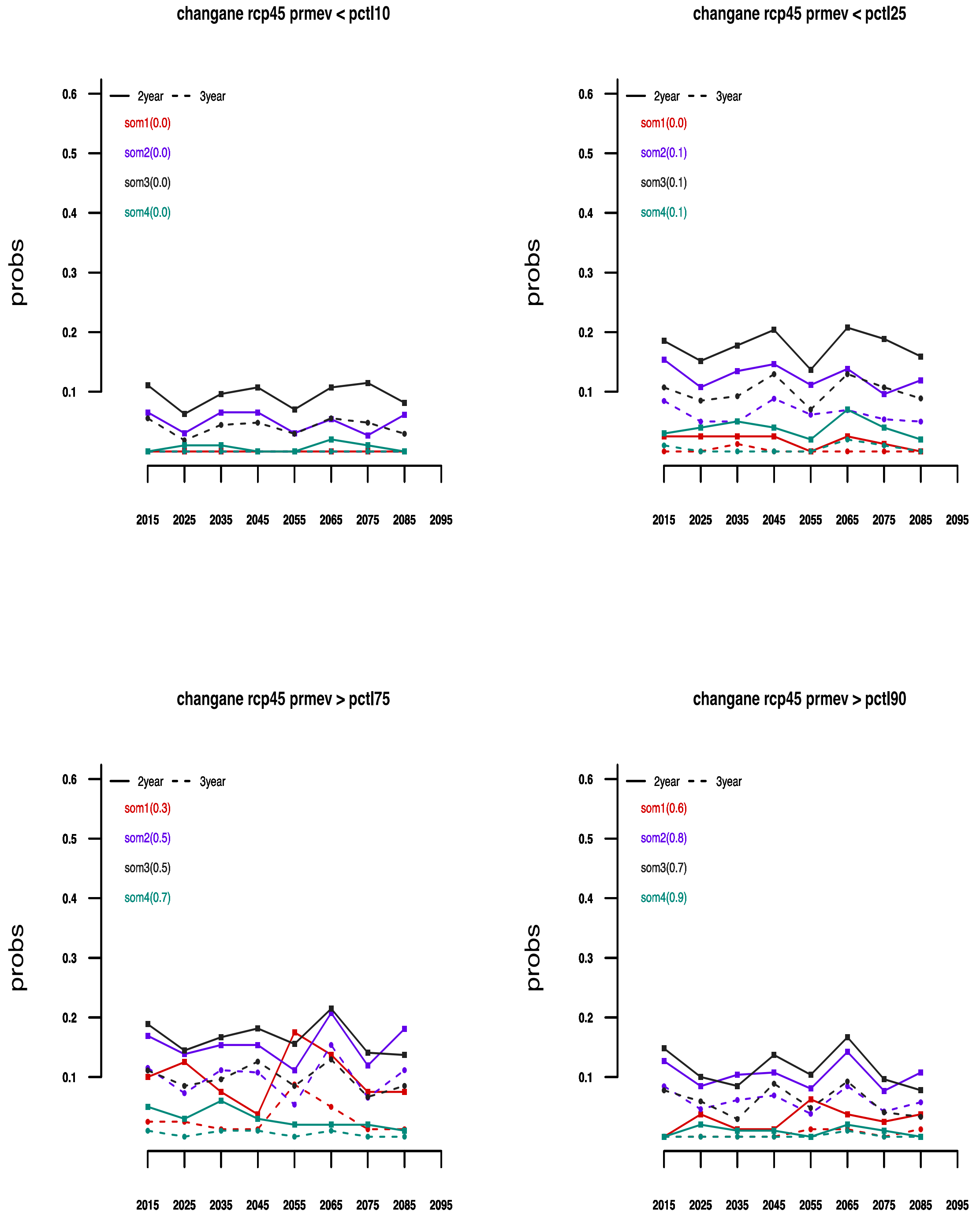


Figure CD10. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD9 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

RCP6.0; temperature vs rainfall

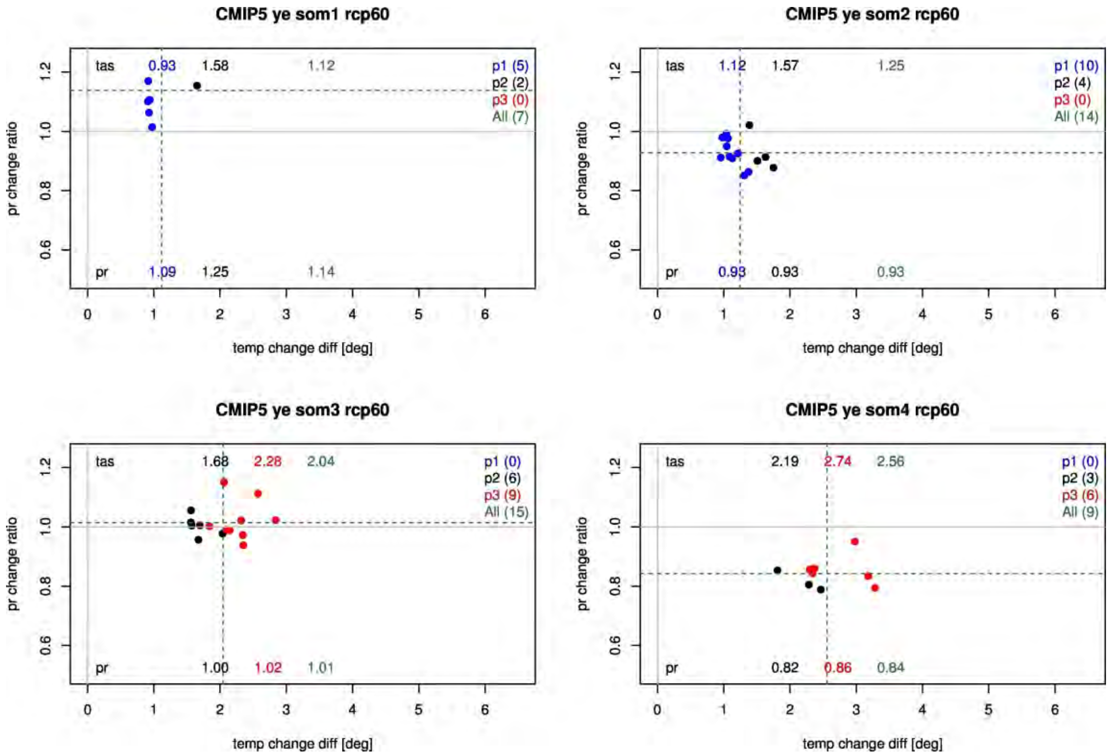


Figure CD11. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Changane Domain under RCP6.0 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 15 projections available in CMIP5 for RCP6.0.

Table CD5a. Scenarios for the year over the Changane Domain under RCP6.0 based on Figure CD11 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
50	2→4	1.00ºC/0.95	1.75ºC/0.90	2.75ºC/0.85
50	1→3	1.00ºC/1.10	1.75ºC/1.00	2.25ºC/1.00

Summary: Two scenarios, one for decreased rainfall the other for little change, with closely similar likelihoods.

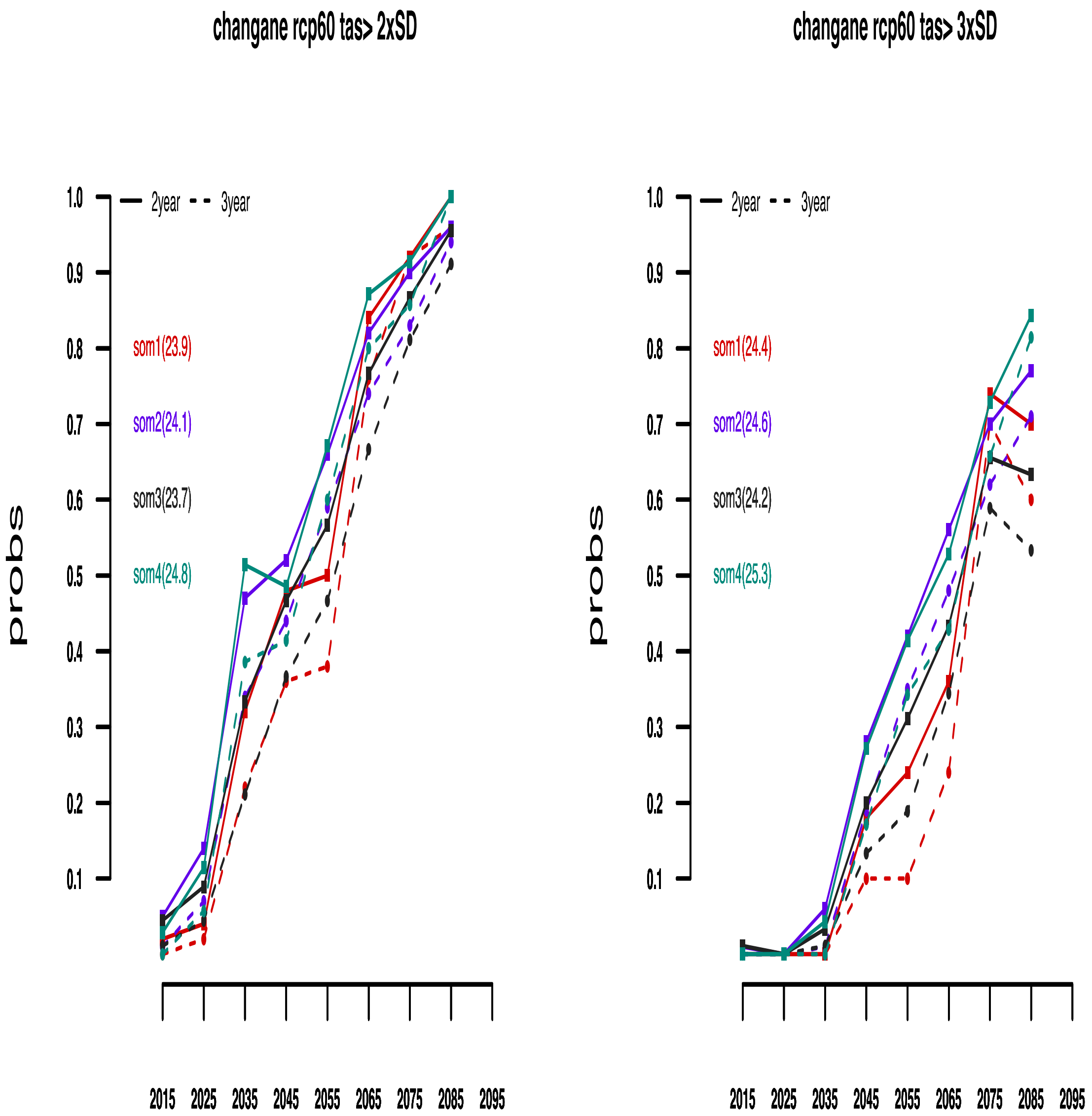


Figure CD12. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD11 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

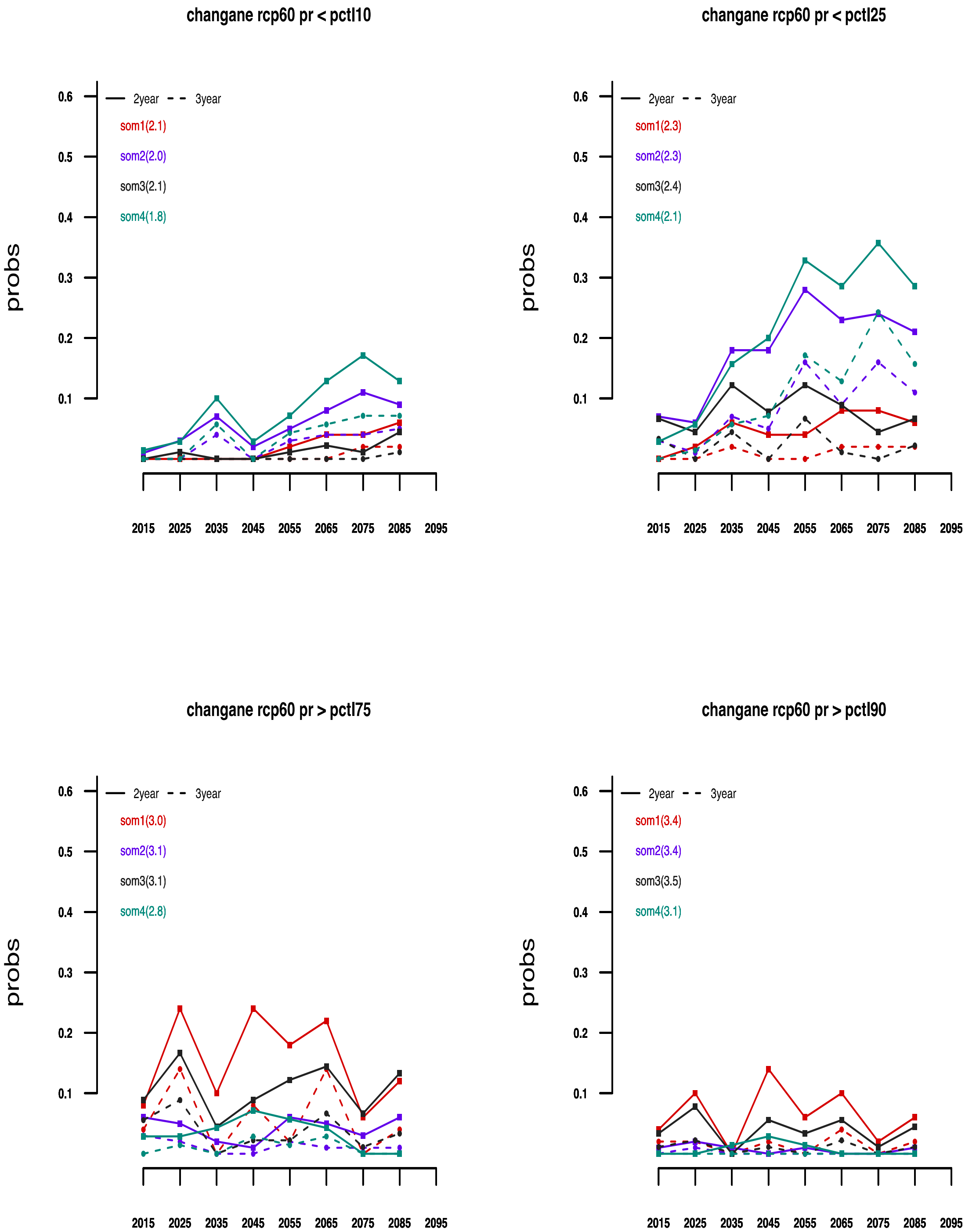


Figure CD13. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD11 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

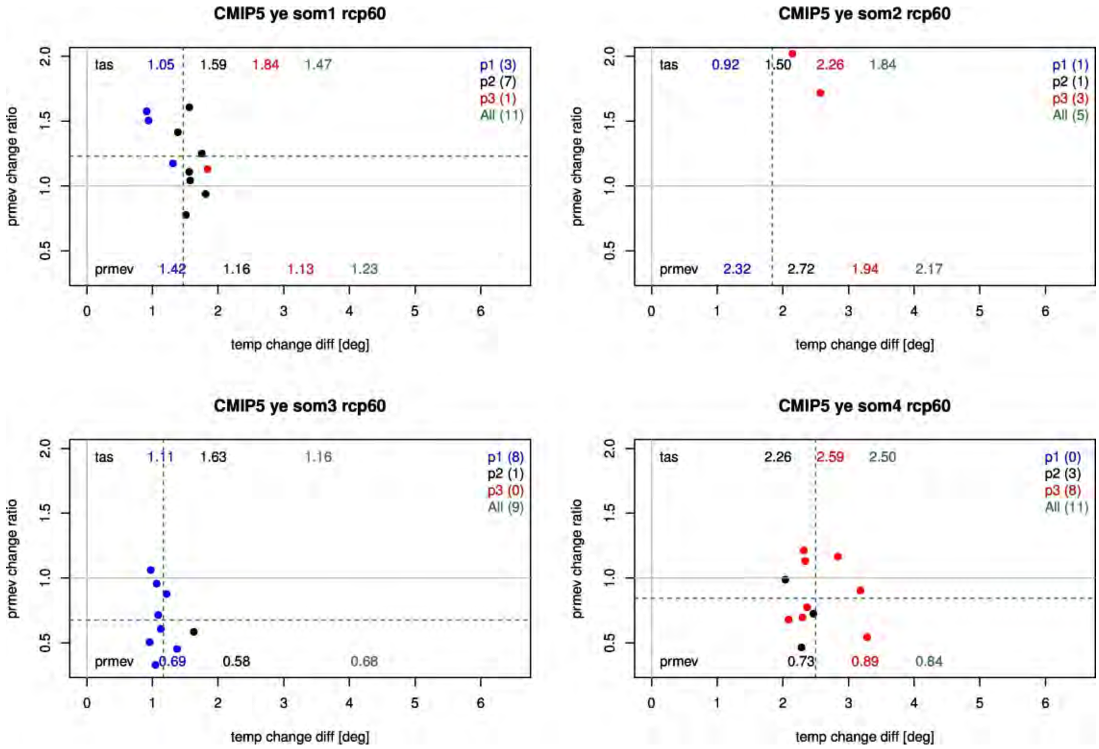


Figure CD14. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Changane Domain under RCP6.0; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 12 projections in CMIP5 for RCP6.0.

Table CD6a. Scenarios for the year over the Changane Domain under RCP6.0 based on Figure CD14 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
55	3→4	1.00ºC/0.70	1.75ºC/0.70	2.50ºC/0.90
45	1→2	1.00ºC/1.40	1.50ºC/1.20	2.00ºC/1.50

Summary: With the limited number of projections available these results need to be treated with caution. Visually there may be a mixture of increased and reduced reduced rainfall less evaporation. Nevertheless, the weight appears to be towards a decrease notwithstanding the small of outlying projections suggesting a substantial increase.

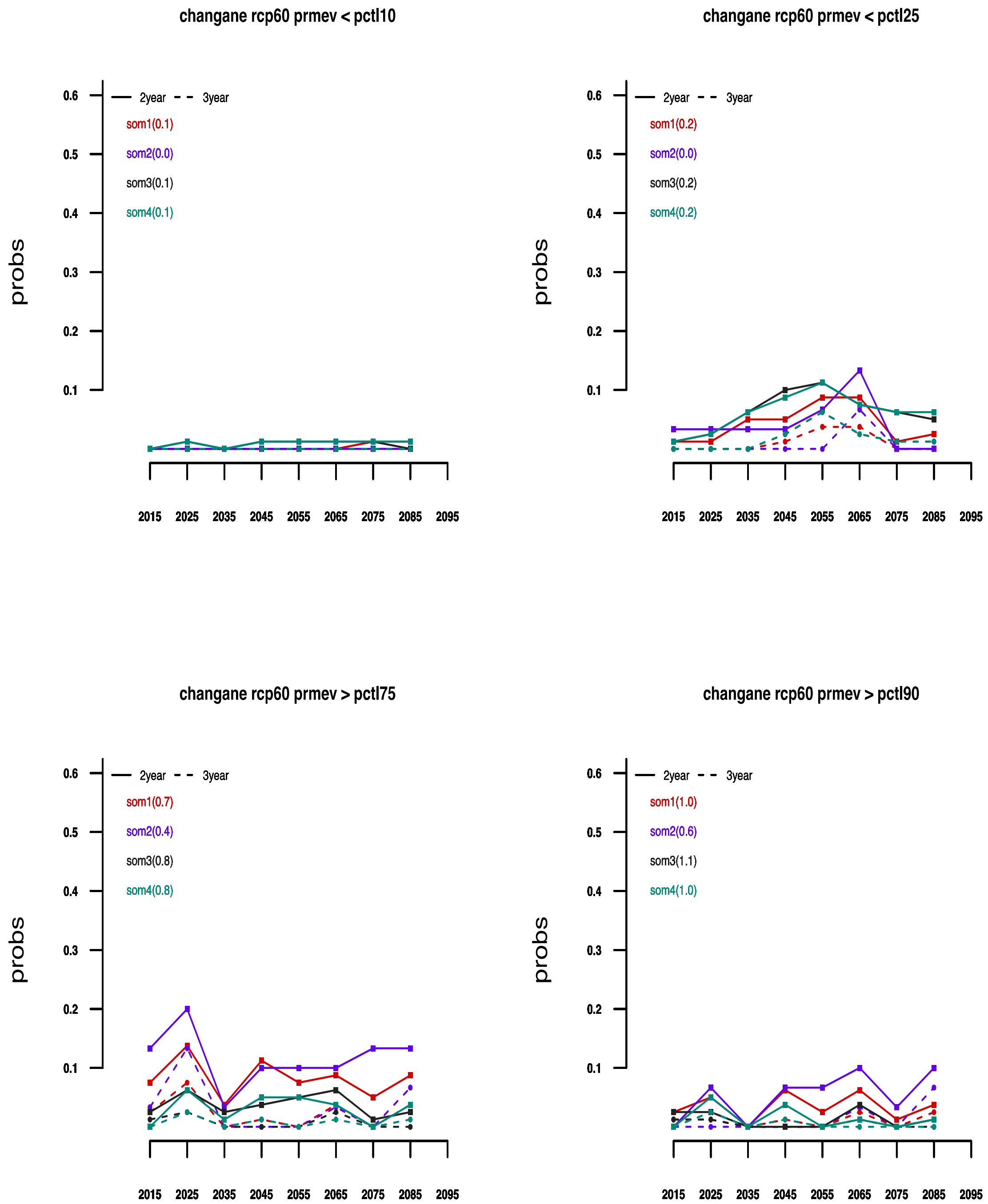


Figure CD131. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD14 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

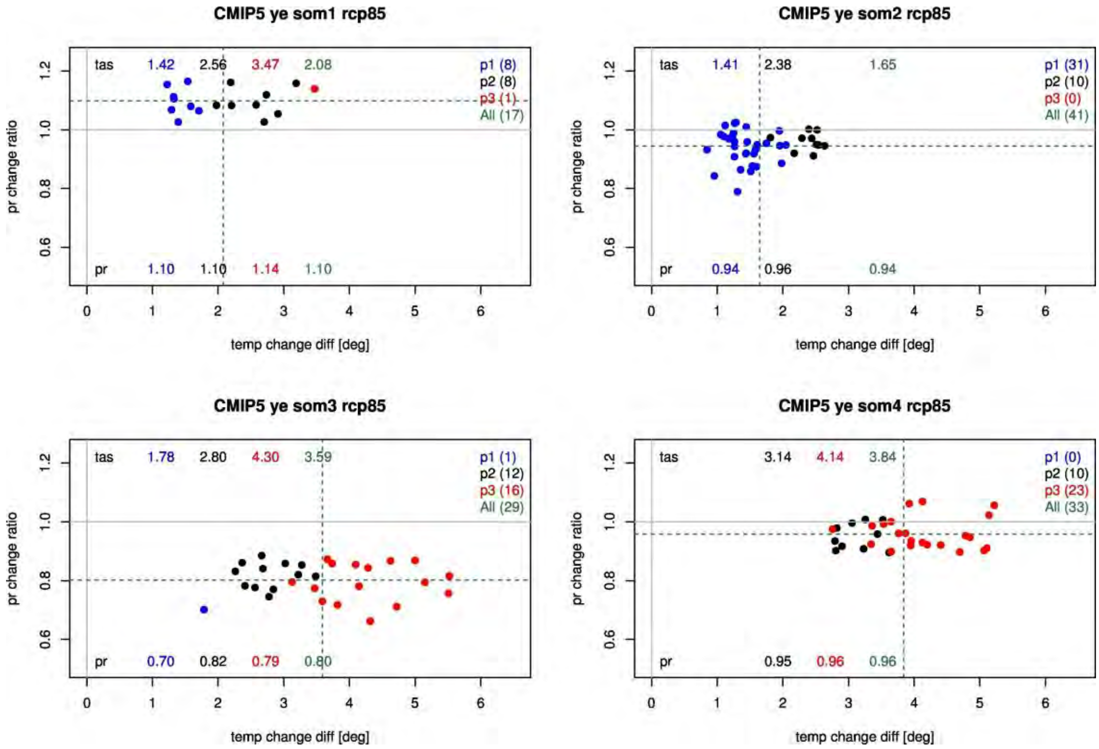
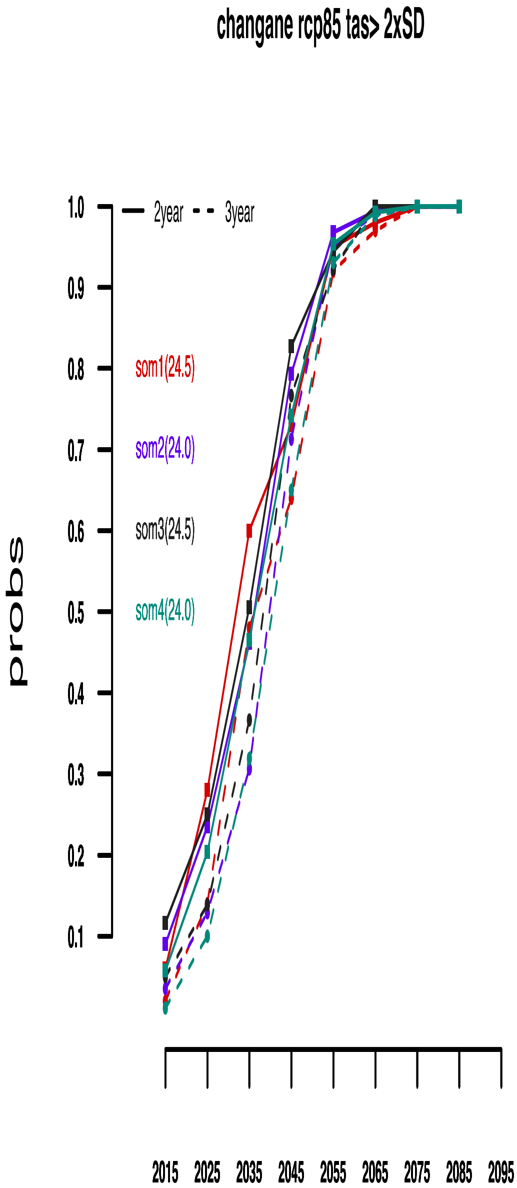


Figure CD16. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Changane Domain under RCP8.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1979-2005 from that single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 40 projections available in CMIP5 for RCP8.5.

Table CD7a. Scenarios for the year over the Changane Domain under RCP8.5 based on Figure CD16 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
45	2→4	1.50ºC/0.95	2.75ºC/0.95	4.25ºC/0.95
40	2→3	1.50ºC/0.95	2.50ºC/0.90	4.25ºC/0.80
15	1	1.50ºC/1.10	2.50ºC/1.10	3.50ºC/1.05

Summary: Most projections lie within soms 2, 3 and 4, with most p1 in som2, all pointing to a future decrease in rainfall. The alternate scenario, with lower likelihood, is for an increase in rainfall.



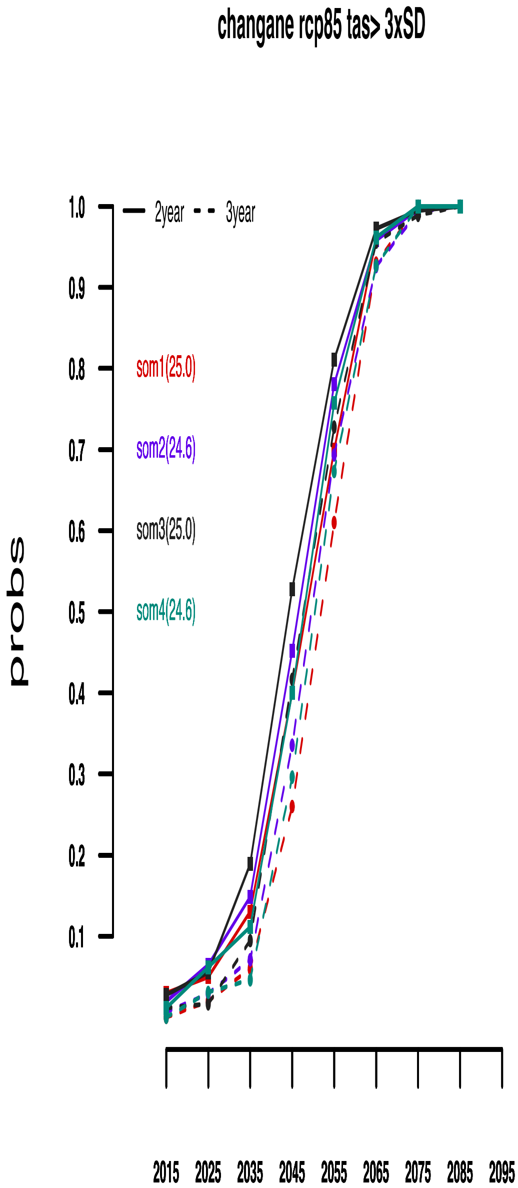


Figure CD17. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD16 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the value of one standard deviation for each som calculated as a mean for contributing models across the base period.

RCP8.5; temperature vs rainfall

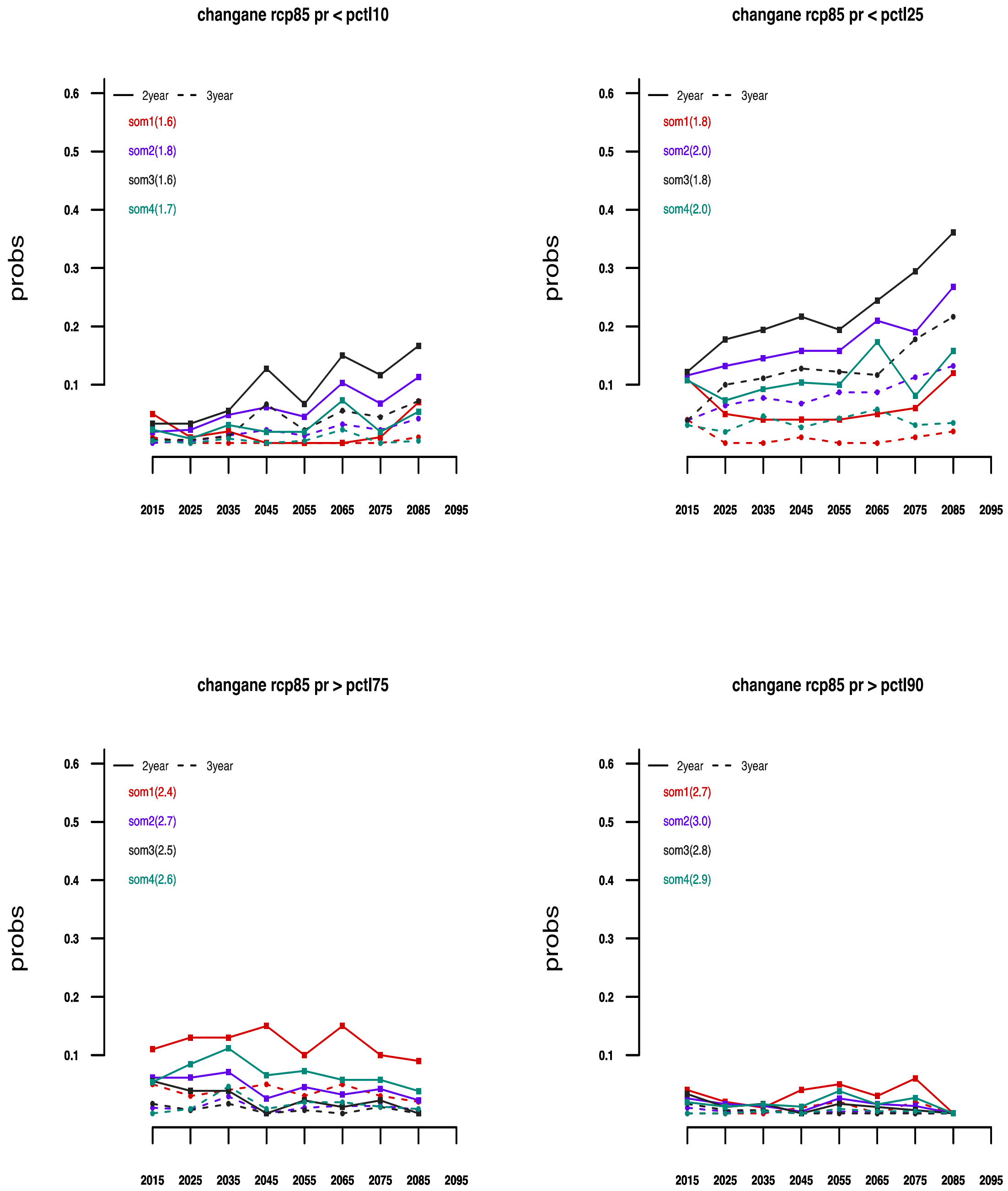


Figure CD18. Decadal probabilities that future annual rainfall totals will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD16 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.

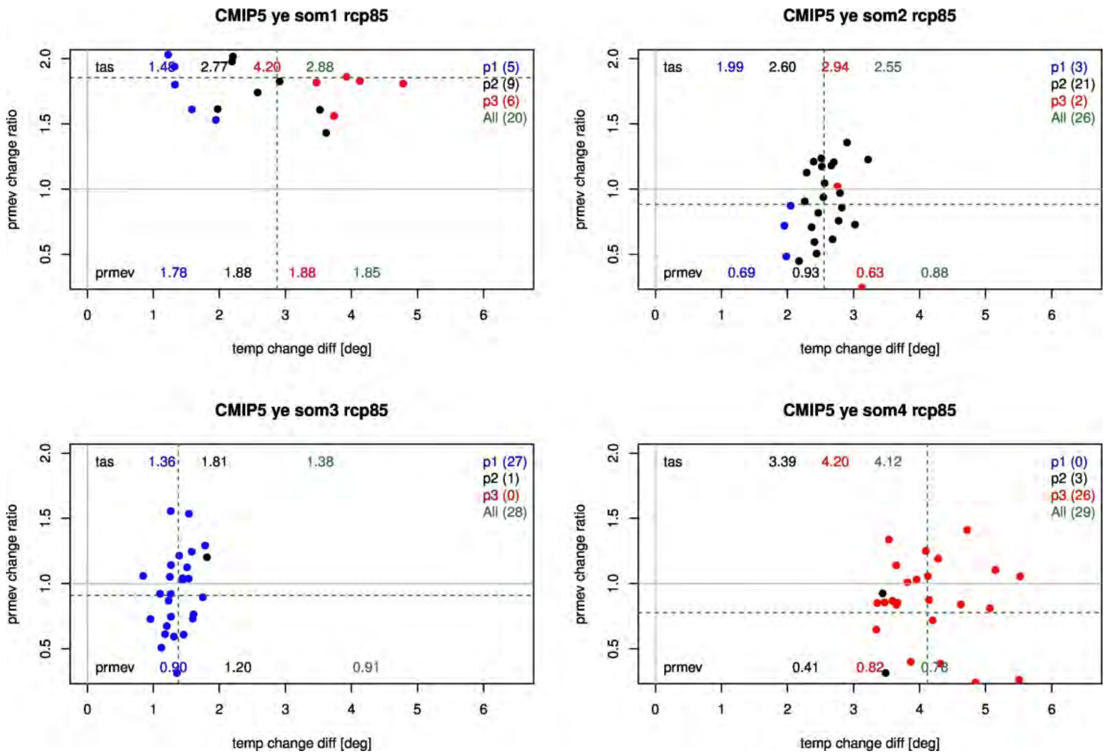


Figure CD19. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Changane Domain under RCP8.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1979-2005 from a single model, with projections for 2025 to 2049 in blue (p1), 2050 to 2074 in black (p2), and 2075 to 2099 in red (p3). Numbers of projections in each time slot are listed colour-coded in the top right-hand of each chart, with overall totals given in green (it is assumed, tentatively, that these values provide an indication of likelihood). Solid grey lines indicate zero change; dotted green lines indicate average changes across all time slots for all projections within a single som chart. Average values of changes are listed colour-coded at the top for temperature (ºC) and at the bottom for rainfall less evaporation (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 33 projections in CMIP5 for RCP8.5.

Table CD8a. Scenarios for the year over the Changane Domain under RCP8.5 based on Figure CD19 above. The first column provides a *suggestion* of relative likelihood of each scenario presented along the rows based on the tentative assumption that likelihood is indicated by the number of projections within each scenario. The second column indicates the chart numbers (see Figure caption) for each scenario. Remaining columns give temperature/rainfall less evaporation changes for each scenario and time slot; temperature changes (all positive) are estimated to 0.25ºC, and rainfall less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
80	3→2→4	1.25ºC/0.90	2.50ºC/0.90	4.25ºC/0.80
20	1	1.50ºC/1.80	2.75ºC/1.90	4.25ºC/1.90

Summary: Despite the substantial number of projections available this analysis appears to separate into a predominately drier scenario together with a low-likelihood wetter scenario (som1) formed by a small number of outlying projections.

RCP8.5; temperature vs rainfall less evaporation

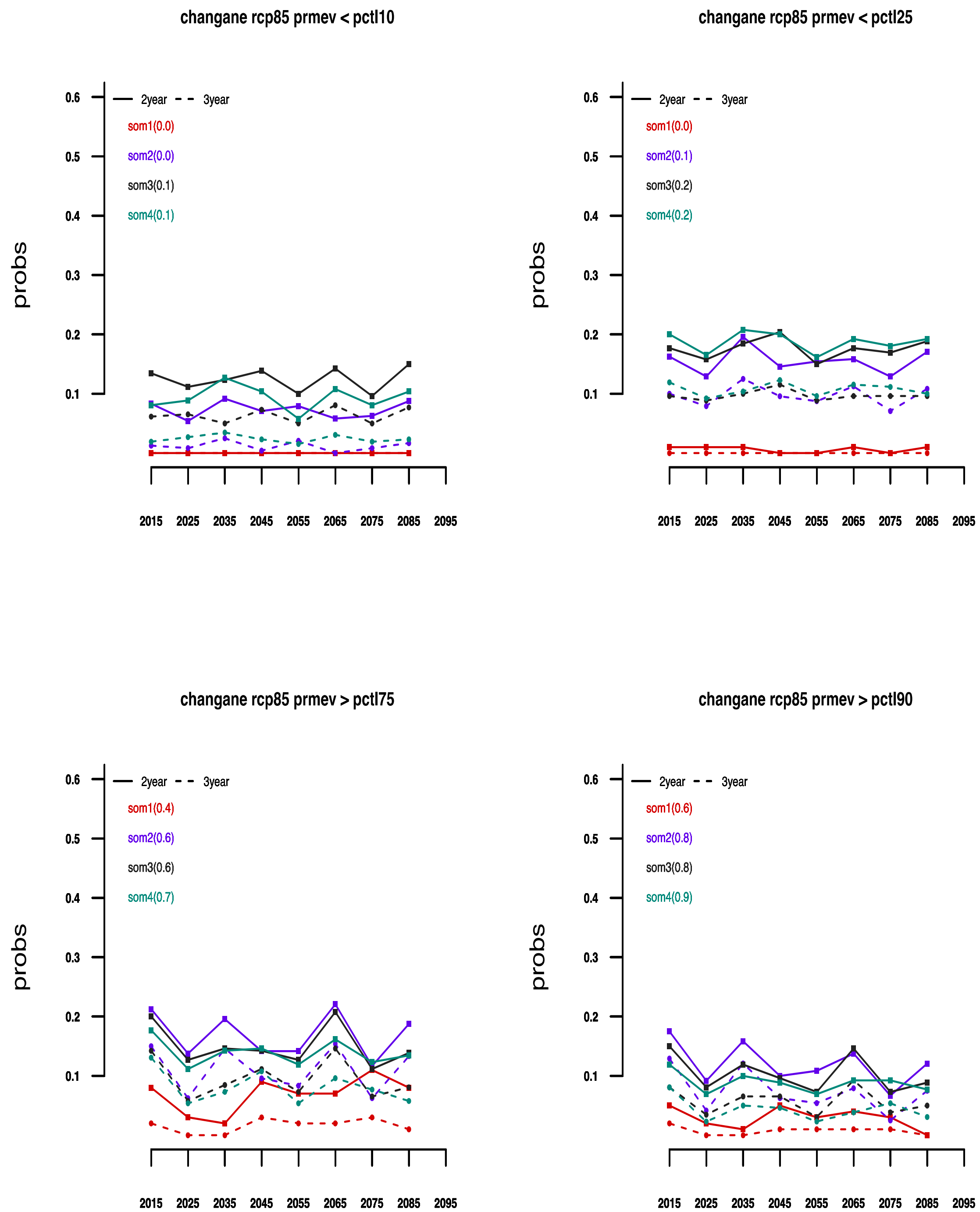


Figure CD20. Decadal probabilities that future annual rainfall less evaporation values will be below the 10th percentile (top left) or the 25th percentile (top right) or will exceed the 75th percentile (bottom left) or the 90th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1979-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD19 are shown in red (som1), blue (soms2), black (som3) and green (som4) (see in-chart legends). Years along the x axes, probabilities along the y axes. Bracketed figures in the legends following the som numbers offer indications of the values of the 10th, 25th, 75th or 90th percentile, as appropriate, for each som calculated as a mean for contributing models across the base period.