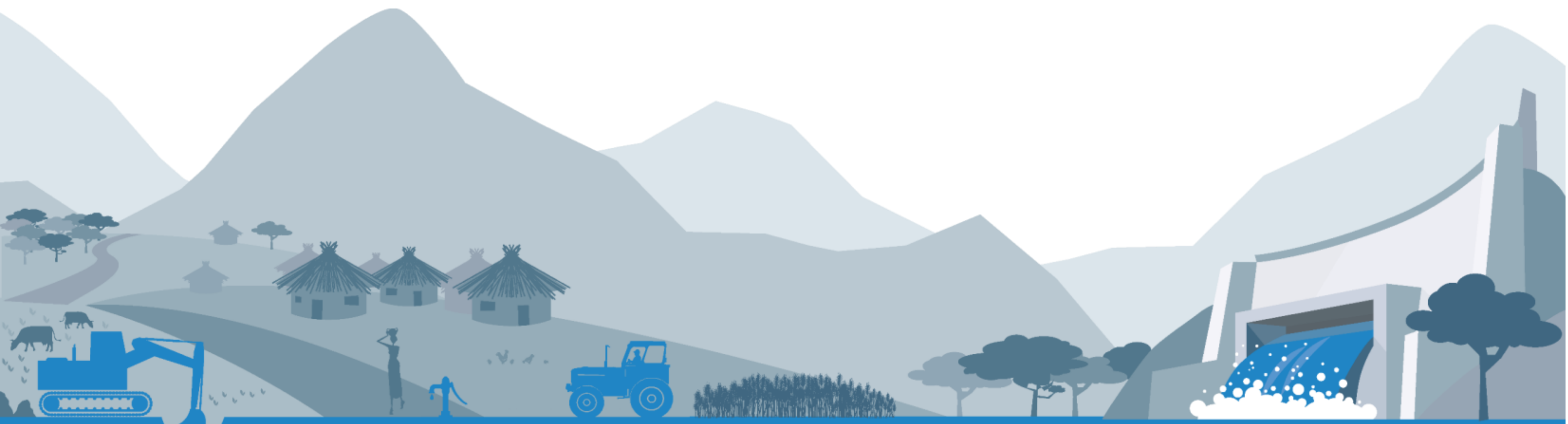
Climate Change Scenarios for the Orange Senqu River Basin

Consolidated Report

January 2019



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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 Orange-Senqu River Basin. Two Domains cover the main headwaters of the Basin, over Lesotho and over the upper Vaal and Wilge rivers, a third lies over the semi-arid regions surrounding the confluence of the Orange and Vaal Rivers, while the fourth covers the arid region of the border between South Africa and Namibia. 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 the two eastern Domains there are indications that annual rainfall distributions will become more spread, with increases in extended wetter and drier spells. The soms analyses produce prominent pathways covering both increases and decreases in rainfall, with similar results for rainfall less evaporation. Further west the signals steadily become stronger for reduced overall rainfall, both from the soms analysis and including from an increase of extended spells of drier weather and a corresponding decrease of wetter spells from the IAV analysis. Nonetheless the IAV assessment for the Confluence Domain suggests that annual rainfall less evaporation values will not change greatly, while that for the Namibia Domain is constrained by the inherent cases of zero or negative annual values in that region, but with a signal for fewer future extended wet spells.

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, or Domains, within the Orange-Senqu Basin as a contribution to the ORASECOM Project (Fig. 1).

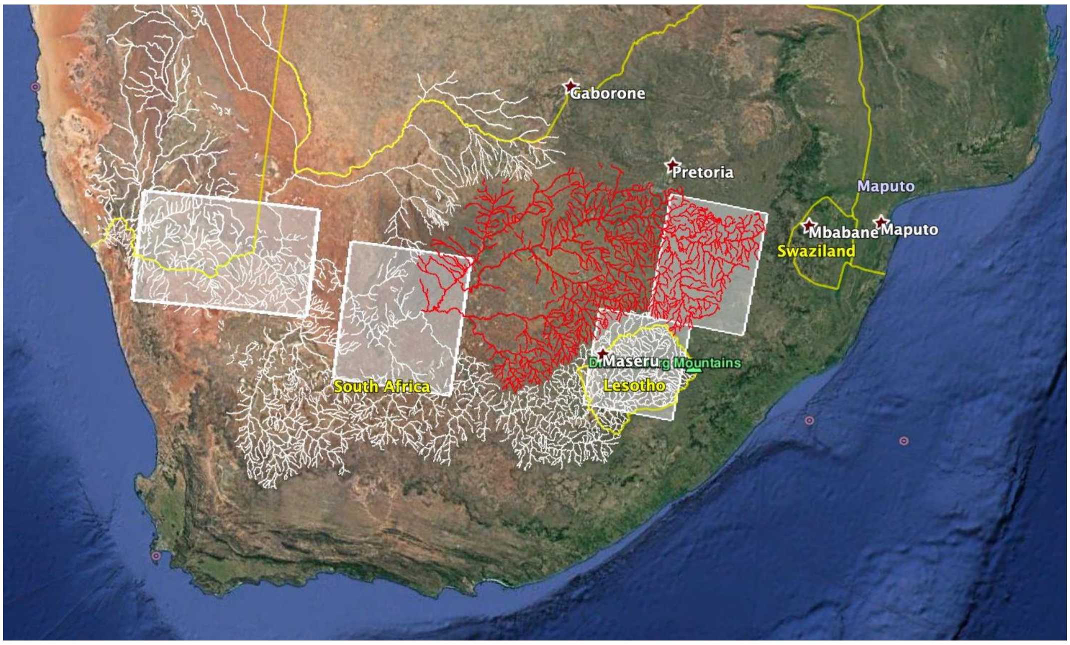


Figure 1. The four regions, or Domains, in the Orange-Senqu Basin for which climate change scenarios have been developed overlaid on the distribution of sub-catchments within the Orange-Senqu Basin (catchment map from www.dwaf.gov.za). The eastern two regions are appropriately the Lesotho and Vaal Domains, centrally is the Confluence Domain, while in the west is the Namibia Domain.

The easternmost areas represent the two major water source regions for the river system, over Lesotho for the Senqu River and further north covering the Vaal and Wilge Basins; some water from the Senqu Basin is available for diversion north to the Wilge River, while the Vaal and Wilge rivers feed the Vaal Dam directly and are major resources for water extraction for the industrial heart of the country and for agriculture. These two areas will be referred to as the Lesotho and the Vaal Domains as appropriate. The central area covers the confluence of the Vaal and Orange Rivers, downstream from the Vanderkloof Dam on the latter, and hence it is the Confluence Domain; the area is semi-arid, with river water used mainly for irrigation and social needs. The fourth area, near the river mouth, is arid with only limited extraction, the Namibia Domain. Climate change scenarios for these four areas offer a useful characterisation for the full basin, over which average rainfall declines towards the west with the summer rainfall peak also delayed progressively towards the west.

The approach used here employs 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 background 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. These pathways are 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 into 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 with 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 prepared for RCP4.5 and RCP8.5 than for the other two. All projections for all RCPs have been used to develop the scenarios in this report. We have focused on 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 on RCP6.0, which is perhaps a more reasonable high scenario than RCP8.5 given plateauing of global CO_2 emissions and global growth of renewables generation in some recent years. 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 estimate 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 on RCP8.5 cannot be dropped entirely at present.

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 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 Orange-Senqu Basin is provided in the Conclusions section.

An independent group of projections, not included in CMIP5 but intended to be included within CMIP6, has been developed by the CSIR in Pretoria using their in-house modified version of the CSIRO stretched-grid model. No details were supplied in time for incorporation into this report.

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' are available from the CMIP5 projections, covering both temperatures and rainfall, although the definitions of the 27 variables indicate a bias in many towards Northern Hemisphere mid-latitude climates and these are thus less relevant, perhaps, in the Orange-Senqu Basin. Experience in similar work with soms as presented here consistently indicates that there is 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. In this report results are given for two of the temperature 'extremes', the two most pertinent to the Orange-Senqu Basin, Warm, and Cold, Spell Duration Indices, WSDI and CSDI respectively.

The rainfall 'extremes', however, are consistently noisy based on earlier research, with limited uniformity across individual soms and suggested 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 IAV statistics have been developed for the complete set of projections. Naturally rainfall IAVs as simulated within each projection differ substantially, one aspect of the complexity of modelling rainfall.

The soms analyses are based on two approaches:

- temperature simulations combined with simulated 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).

Two approaches have been used as, in preliminary work using temperature against rainfall less evaporation, it was determined that for certain models rainfall roughly equalled evaporation during the base period (see below). 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. This issue does not arise when rainfall alone is used, so the first approach to soms using just temperature and rainfall provides a useful background and comparison to the second approach using temperature with rainfall less evaporation. After testing various approaches, a simple subjective selection was used to remove projections producing unrealistically high future rainfall less evaporation ratios.

The absolute temperature/rainfall/evaporation climatologies for each model may differ from observed climatologies and rather than attempting to correct this directly the standard approach is to calculate future differences from modelled values over a past base period for each projection independently. The base period used here is 1986-2005, as used in the IPCC AR5. 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.

Simulations for 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 ‘future’ 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 often by a single central year, namely 2040, 2065 and 2080; on some 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 geographical areas for the som analyses)
- 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 som (see results towards the latter parts of the reports for each Domain)
    - Preliminary assessment to check and correct the issue of near-zero base period values of rainfall less evaporation as described above
    - Results for each som analysis (i.e. for each RCP for each Domain) examined independently to develop suggested scenarios to ensure, as far as possible, no bias is introduced from previous assessments
    - Suggested scenarios tabulated in the report
    - A brief justification for each set of suggested scenarios added as an *aide memoire*

- Once the above completed, all suggested scenarios are collated into an overview section presented immediately after the introduction section in the reports 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 are then provided through study of the IAV results.

The IAV statistics focus on estimated probabilities for each som of future periods of either two or three years successively over which, in comparison to annual values calculated across the base period, annual temperatures may increase to 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). 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.

The background values of standard deviations and percentiles used for the IAV assessments have been calculated from annual values as simulated independently by each climate model across the base period, 1986-2005. 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. 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 amongst themselves quite substantially over the base period, and hence it is not possible to undertake the calculations by simple averaging of absolute values 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 Orange-Senqu Basin in brief

A recent rainfall climatology for South Africa is illustrated in Figure 2 derived by the Tropical Rainfall Measuring Mission (TRMM) satellite. The comparatively high rainfall in the “water tower” regions of Lesotho and the headwaters of the Vaal/Wilge system, covered by the Lesotho and Vaal Domains, reaches its maxima in November to February. The westward progression of the heavier rainfalls through the season is apparent, with a maximum over the Confluence Domain around February to March. Rainfall in the Namibia Domain is largely from summer storms, although occasional winter rainfall may reach the area, as hinted at by the coverage of rainfall northwards from the Cape along the west coast during the cooler season.

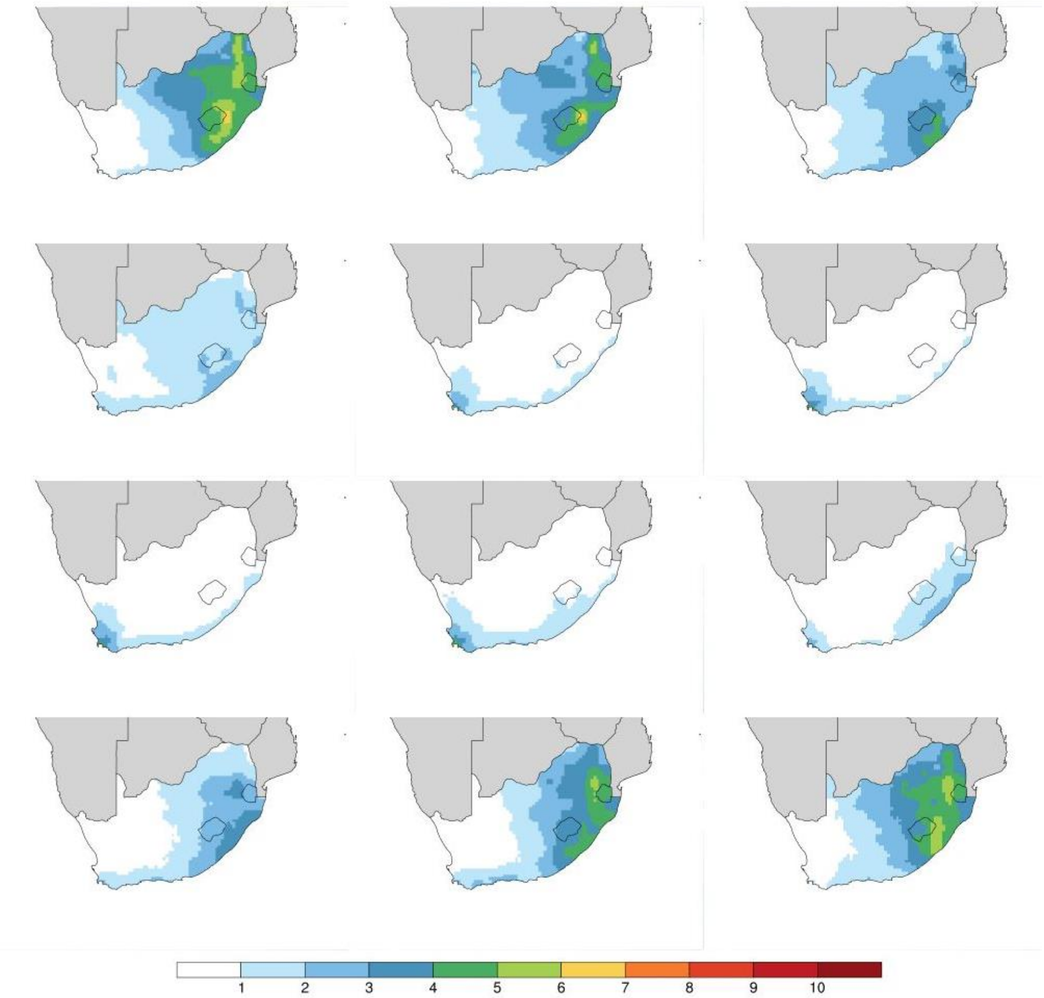


Figure 2. Monthly rainfall climatology according to TRMM; units are mm/day as per legend at bottom. Months read across then down, starting with January at top left, December at bottom right.

3 Some basic details of the CMIP5 projections

Temperature rises. Average temperature rises (the average across all CMIP5 projections), from the ensemble mean (Fig. 3), are likely familiar from the IPCC AR5. Higher rises are to be expected with greater concentrations of atmospheric CO_2, the highest under RCP8.5 reaching in excess of 5ºC by P3 (2075-2099)[1]. Modelled, if not actual, increases are monotonic in time, i.e. there is a steady increase throughout, and are greatest in the central parts of the subcontinent and 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 (Fig. 4). It reaches about 1ºC over the central parts in P3, although a monotonic increase may not be apparent in time and CO_2 concentrations (RCPs) 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.

1 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.

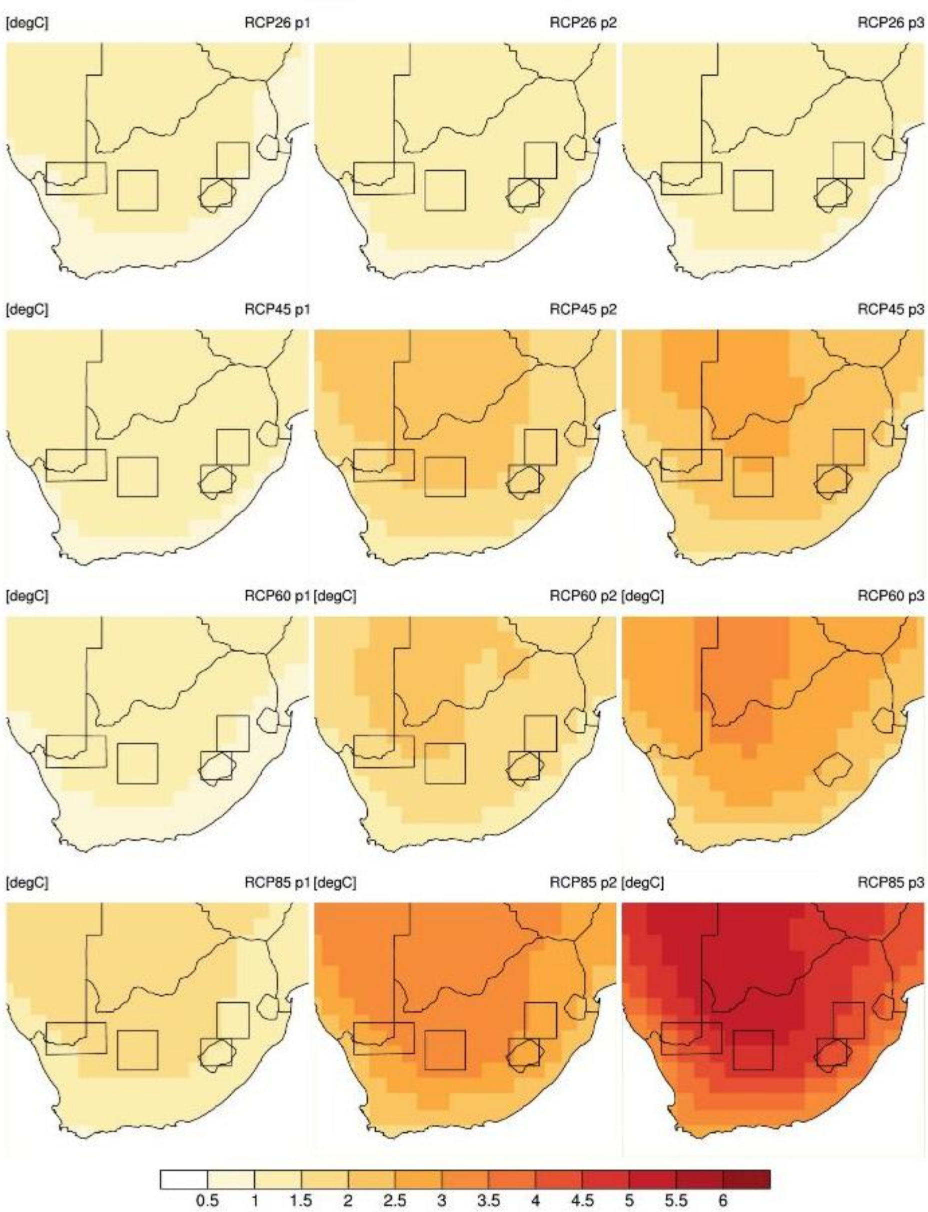


Figure 3. Average temperature increases from 1986-2005 across all CMIP5 projections according to the legend at the bottom. The top row is for RCP2.6, the second RCP4.5, the third RCP 6.0 and the bottom row RCP8.5. The left-hand column covers P1 (2025-2049), the central column P2 (2050-2074) and the right-hand column P3 (2075-2099). Blocks indicate the Domains over which the soms have been calculated.

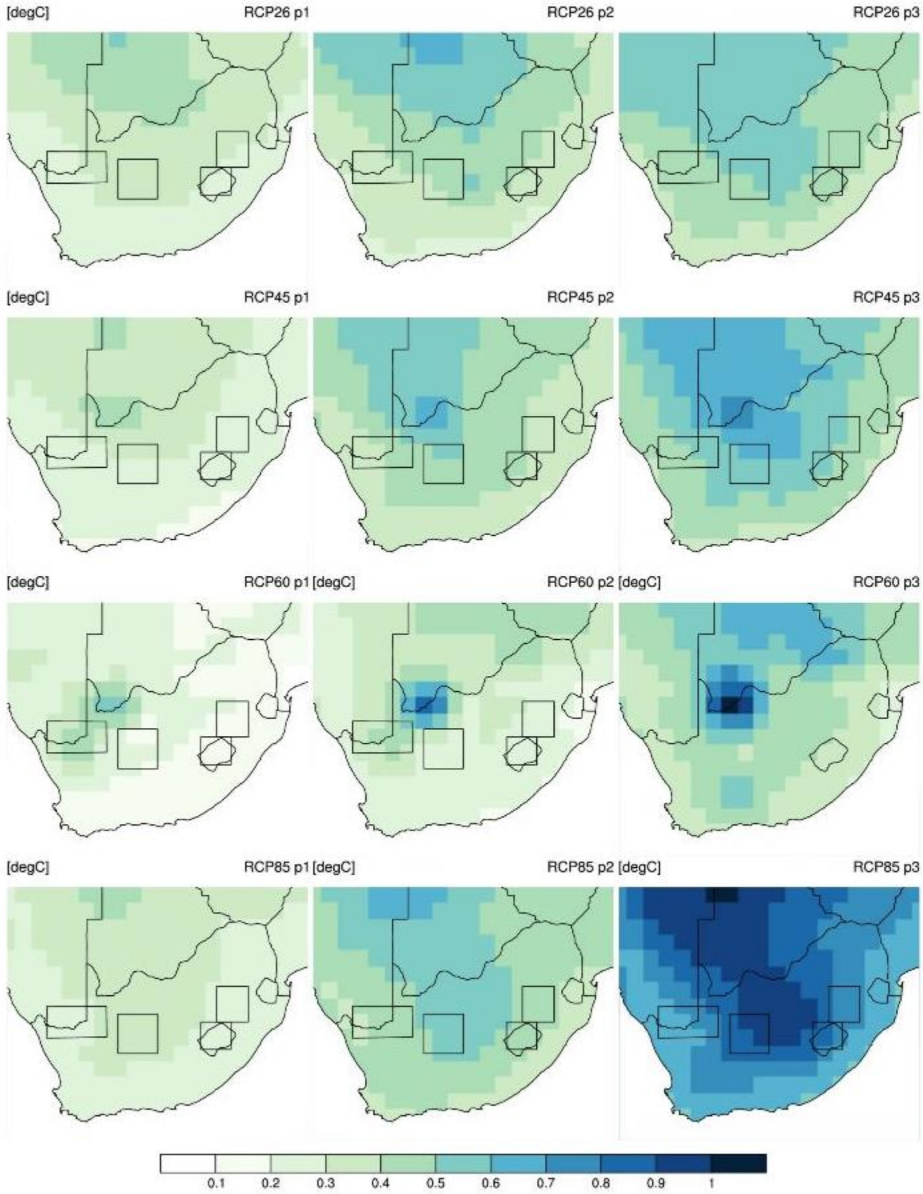


Figure 4. As Figure 3 but for the standard deviation of the temperature rises across the full CMIP5 projections

Changes in rainfall. According to the ensemble mean rainfall will decrease across the entire Orange-Senqu Basin, with the exception of a region, variable in size and location, around the headwater Domains in Lesotho and of the Vaal, with extension into Kwazulu-Natal, in terms of time and RCP (Fig. 5). The results have been calculated as ratios to the mean annual totals simulated by each model within the base period of 1986-2005. There is a general, but not absolute, pattern of greater rainfall decreases with higher RCPs[2]; maximum values are in the west and reach over 20% under RCP8.5. 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 changes in current rainfall patterns are likely 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. 6). Lowest values, suggesting highest confidence (with caution) in the

2 While it is reasonable to assume to a first approximation that temperatures will rise with increasing CO_2 concentrations the same is not true necessarily for changes in rainfall; temperature adjustments across the continents and oceans may result in changes to atmospheric circulation patterns that might either increase or decrease rainfall at a given location over different future time periods. There may also be changes in the distribution of extremes.

ensemble mean changes, are in the east, typical covering the Lesotho and Vaal Domains, with highest along the north-west coast, extending to the Namibia Domain and, in some cases, to the Confluence Domain.

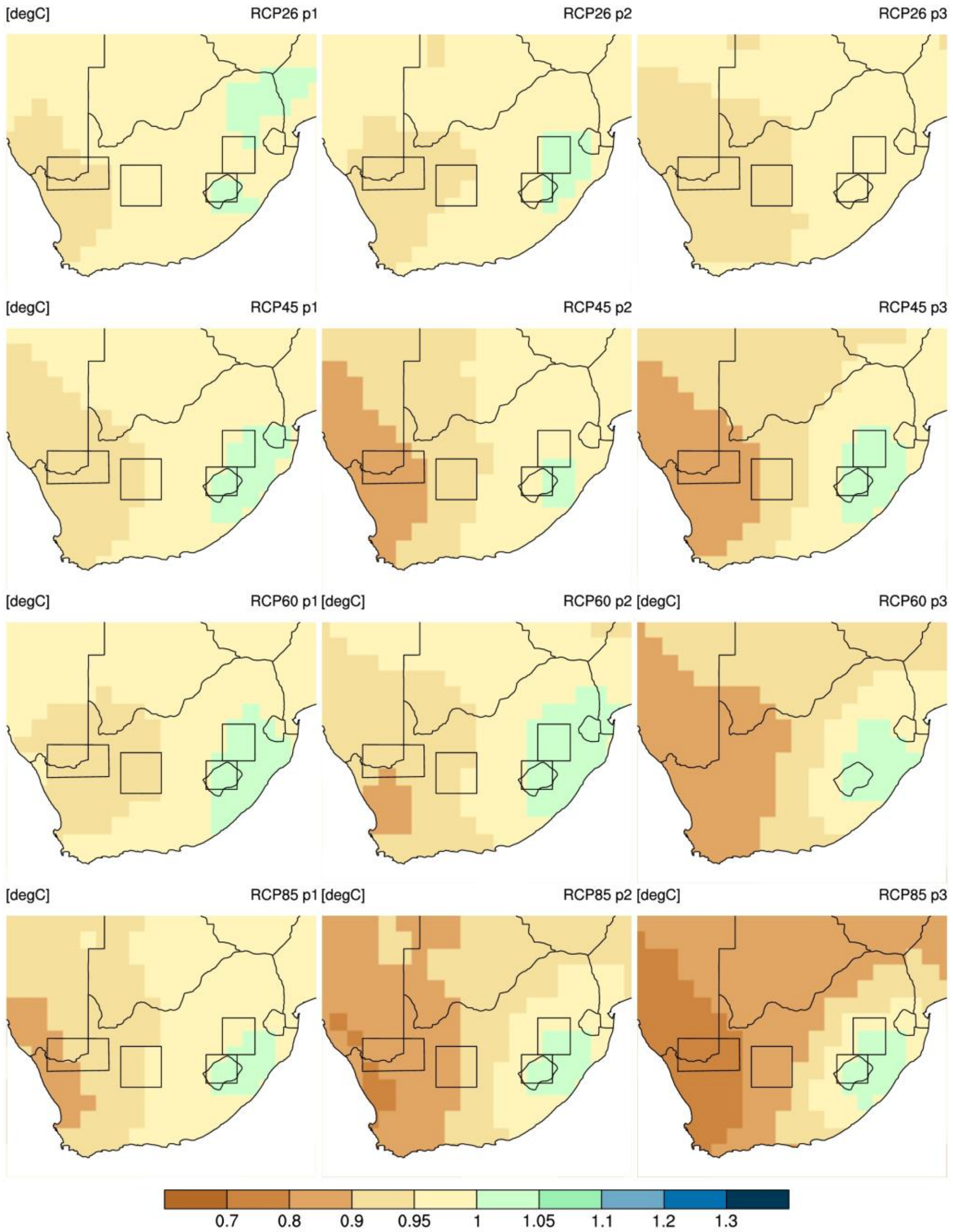


Figure 5. As Figure 3 but for changes in total annual rainfall as a ratio to that during the base period of 1986-2005.

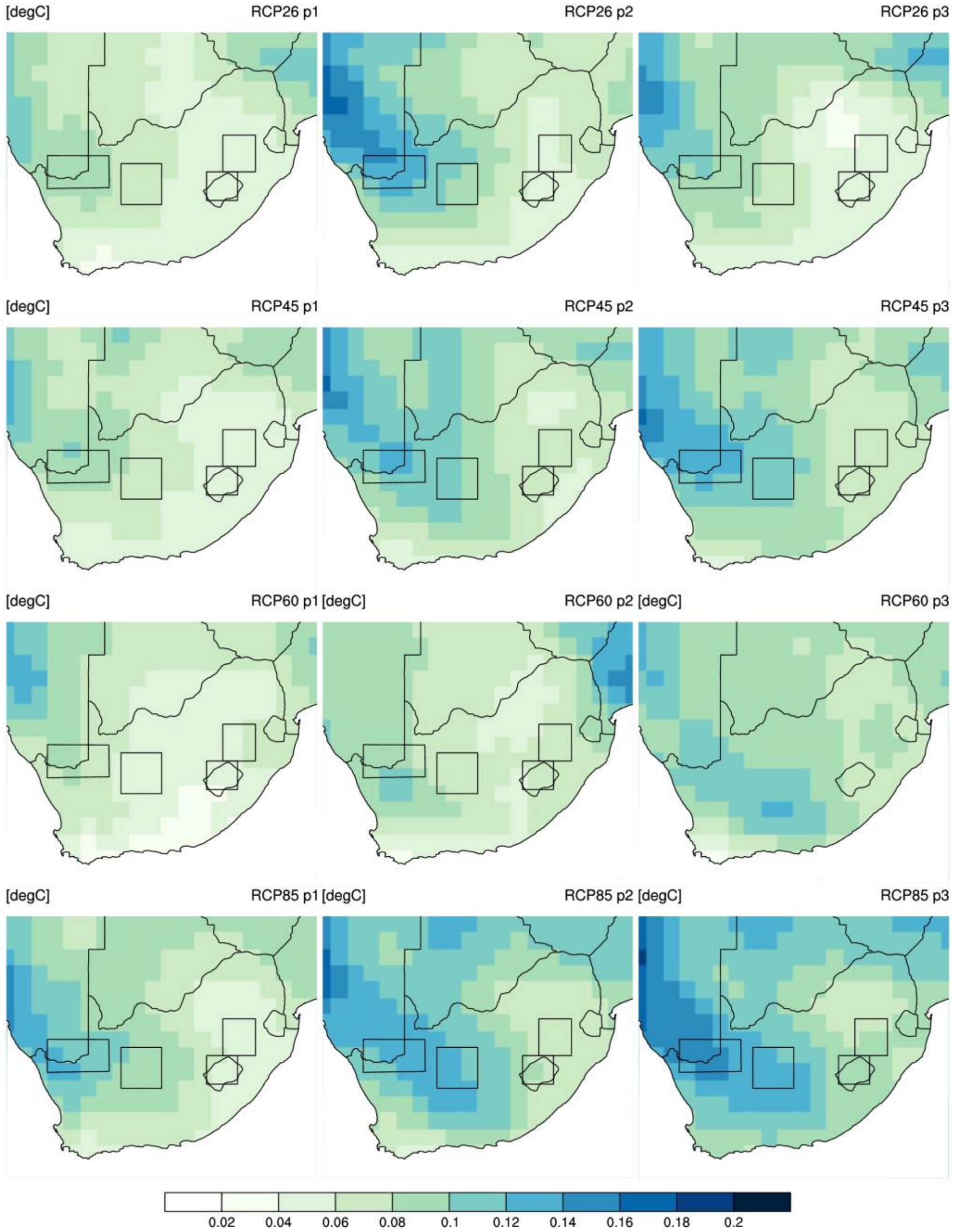


Figure 6. As Figure 4 but for standard deviations of the ratios of the rainfall changes.

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 as also simulated by each model for the base period 1986-2005. Evaporation, of course, responds to changing temperatures, and thus the rainfall less evaporation measure may be 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 the country, but increases in general around the coasts (Fig. 7). The distributions are, perhaps, a little more noisy than those for temperature and rainfall increases, but this might be expected given the issues of simulating both rainfall and evaporation in the models. Regions most affected might expect a reduction to below 70% of recent values according to this measure, perhaps including the Confluence Domain (conversely increases might exceed 30% in limited regions, mainly outside the Orange-

Senqu Basin). Decreases 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 values according to the ensemble means.

The water tower regions in the east are relatively less affected than some central areas, with any reductions limited to less than 5%, and with a hint of possible increases (in certain periods under certain RCPs) presumably in part allied to the increased rainfall projected in the ensemble mean (Fig. 5). Future changes across the Namibia Domain might also be positive according to these data despite a consistent ensemble mean projection of decreased rainfall in this area. Nevertheless, some caution should be attached to this observation for the Namibia Domain as the detailed results for this Domain presented elsewhere in this report indicate a rather skewed distribution of annual values that might affect the means.

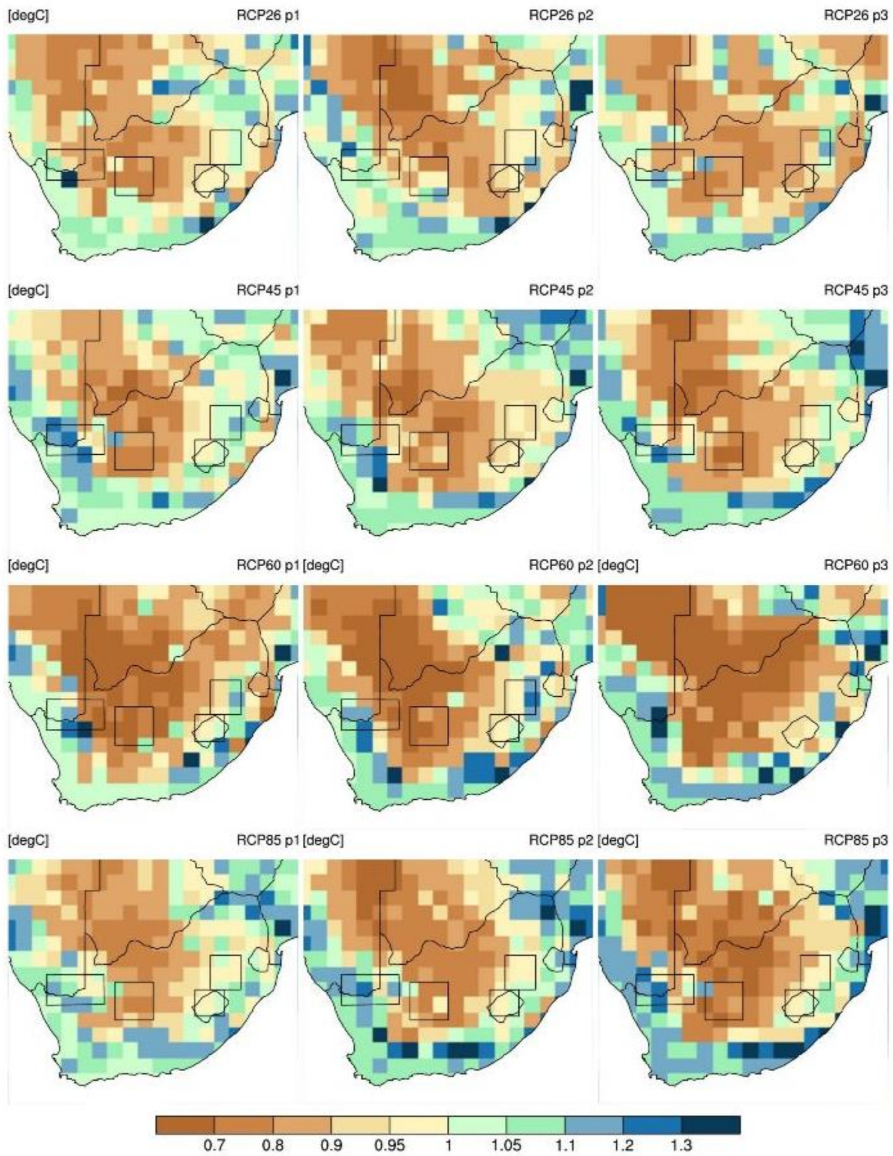


Figure 7. As Figure 3 but for the mean across the full CMIP5 projections for the difference between the rainfall and the simulated evaporation expressed as a ratio across the 1986-2005 mean values.

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. 8). Nevertheless, there does seem to be a basic pattern of lower standard deviations across the regions with reduced RLE values in the ensemble mean, including perhaps the three easternmost Domains, and higher values over areas with increased RLE values (apparently consistent with results for rainfall alone in Figure 6). If correct, then this indicates that the models are more consistent amongst themselves in simulating future reduced RLE values over the central regions than they are in simulating increases around the coasts.

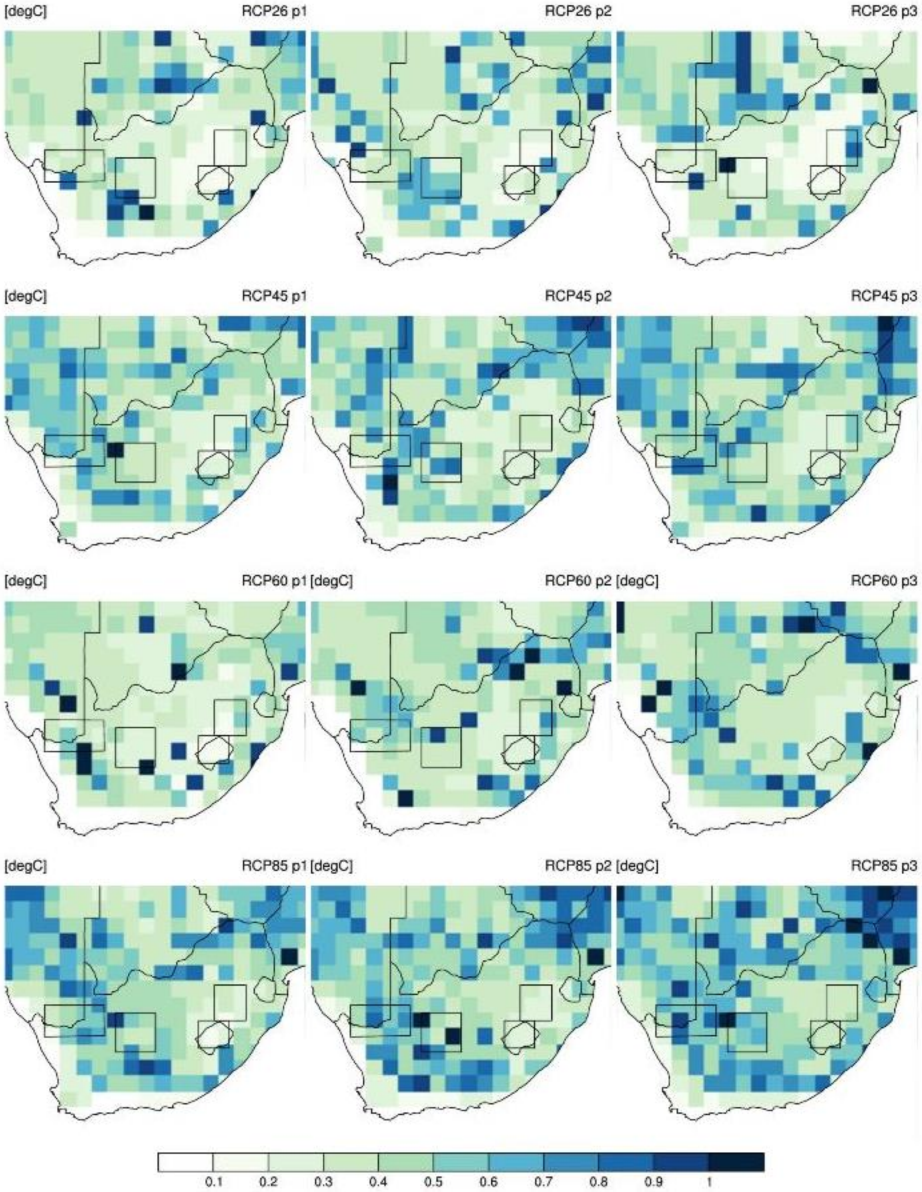


Figure 8. As Figure 4 but for standard deviations of the ratios of the differences between the rainfall and evaporation.

Of possible interest is that the distribution of lowest future ratios of rainfall in Figure 7 appears to replicate the climatological rainfall distribution from the major rain-bearing systems over the central parts of South Africa, the tropical-temperate troughs, or cloud bands (although no similar feature appears in the rainfall charts in Figure 5). Do these results suggest a change in water availability associated with these systems?

4 Scenarios from self-organising maps and their inter-annual variability

For each Domain and for each RCP suggested scenarios have been created, as summarised in the separate documents for each Domain. From these 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 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 RCP analyses for each of the Domains are summarised in the following, covering results from both the soms and the IAV analyses, 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 summaries are on rainfall and rainfall less evaporation (RLE) changes. The sequence of presentation is from the headwaters Domains, Lesotho and Vaal, then downriver to the Confluence and, finally, the Namibia Domains:

Lesotho Domain: Rainfall changes in both directions appear in all suggested scenarios for individual RCPs, with a clear weighting towards an increase, or at least little change from current conditions, in all except RCP8.5, for which the likelihoods of increase and decrease are similar. The picture is a little more complex for RLE. For RCP2.6 there is a distinct bias towards future drier conditions, with an estimate of a 75% likelihood of drier conditions in some form. For the remaining RCPs there is roughly a 50-50 split in likelihoods between drier and wetter conditions. Nevertheless the recommended scenarios offer marginally higher likelihood towards an increase in RLE.

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 RLE 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.

Vaal Domain: There is a distinct weight towards either continuance of current rainfall conditions or, more frequently, increased rainfall for all RCPs, an increase that is reflected in the recommended scenarios. As has been the case often in these soms analyses, RCP8.5 is not only responsible for higher temperature rises but also for relative equality between probabilities of rises and decreases in rainfall. There are similar likelihoods of increased and of decreased rainfall less evaporation, even for RCP8.5, unlike the case for the rainfall only assessment. There might be a slight bias towards warmer temperatures with reduced water availability; warmest temperatures, naturally, occur with RCP8.5.

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 RLE likelihoods of extended 2- and 3-years spells below and above historical annual 10th and 90th percentiles do not change significantly in time, although chances perhaps increase a little under RCP6.0 and RCP8.5, but those for the 25th and 90th percentiles do (although not for all soms) for most RCPs, suggesting an increase in spread of annual values and with possible slight bias towards drier conditions.

Confluence Domain: There is a distinct weight towards reduced future rainfall for all RCPs that is reflected in the recommended scenarios where at best rainfall stays steady or decreases by 5%, or a little more. In the case of RCP8.5 only, reductions in rainfall are present in the recommended scenarios together with greater temperature increases than in other RCPs. There is perhaps a lesser likelihood of a decrease in RLE than in rainfall alone, presumably related in some manner to increased temperatures, but the overall weight remains for a decrease.

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. Frequencies of periods of relatively heavy and relative light rainfall, as assessed through the IAV analyses, indicate that the future climate will, on the whole, move towards drier conditions. But that conclusion is not replicated in the RLE likelihoods, which broadly suggest a continuation of current conditions. In other words, any adjustments in rainfall are balanced approximately by corresponding adjustments in evaporation in the projections – caveats regarding this result are presented later.

Namibia Domain: Rainfall changes are certainly weighted towards decreases in all suggested scenarios for all RCPs. The picture is a little more complex for RLE in comparison, with greater likelihoods of increased RLE.

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. Frequencies of periods of relatively heavy and relative light rainfall, as assessed through the IAV analyses, indicate that the future climate will, on the whole, move towards drier conditions. Limited conclusions may be drawn from the RLE IAV analyses, however, other than there appear to be future decreases in the heavier rainfall events.

The main characteristics of the basic soms 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 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%; • - following an arrow indicates little change.

	Rainfall		*Rainfall less evaporation*	
Domain	*Higher*	*Lower*	*Higher*	*Lower*
Lesotho	🡅	🡇	🡇	🡅
Vaal	🡅	🡇	🡅◆	🡇◆
Confluence	🡇	🡅•	🡇	🡅•
Namibia	🡇	🡇	🡇	🡅

The results for rainfall as summarised in Table 1 indicate that the directions of change are opposed between higher and lower likelihoods, except perhaps for the Confluence Domain where the lower likelihood indication is for little change from current conditions, and certainly for the Namibia Domain for which both recommended scenarios indicate future decreases in rainfall. Thus, in the headwater areas the greater likelihood is for increased rainfall, whereas lower down the basin it is for decreased.

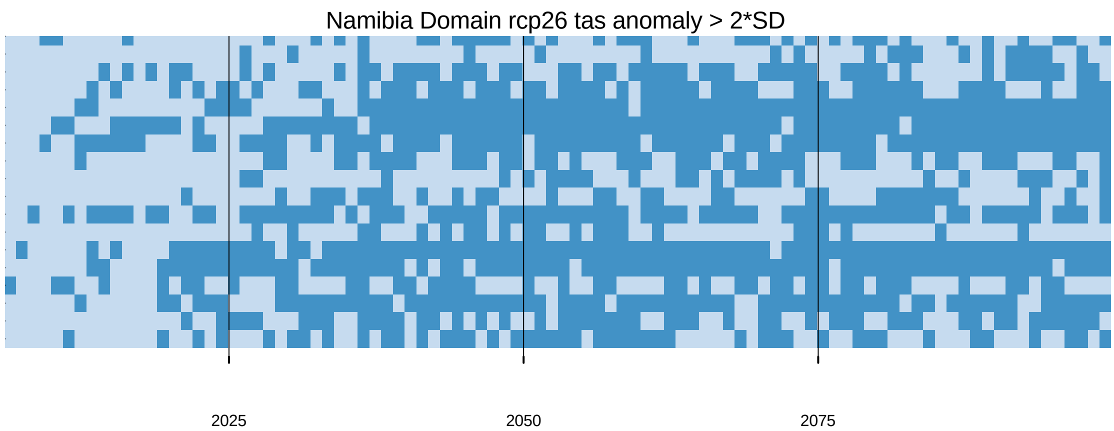
Directions of change are always opposed for higher and lower likelihoods of RLE, with decreases most likely throughout, except perhaps for the Vaal Domain although here the likelihoods for increases and decreases are similar. Rainfall less evaporation is, of course, a better measure of water availability 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 2050s, and above three standard deviations by the 2060s 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 60% for two standard deviations and 40% for three standard deviations.

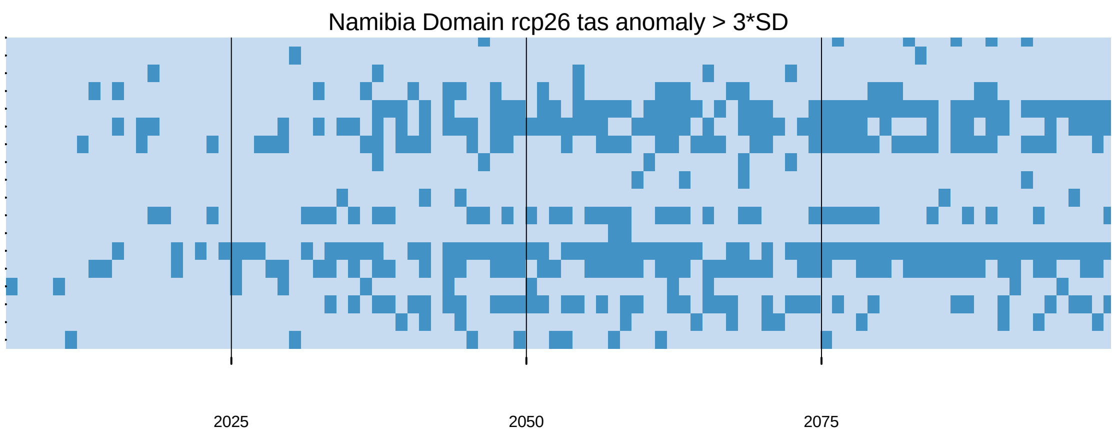
In previous reports values for the IPCC 'extreme' statistics, calculated from the CMIP5 projections, have been provided. The most useful temperature 'extremes' for the latitudes of the Orange-Senqu Basin are the Warm and Cold Spell Duration Indices, WSDI and CSDI, defined as the annual number of days 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 9 illustrate the individual years in which annual temperatures exceed two and three standard deviations for each projection for the Namibia Domain under RCP2.6 and RCP8.5 separately:

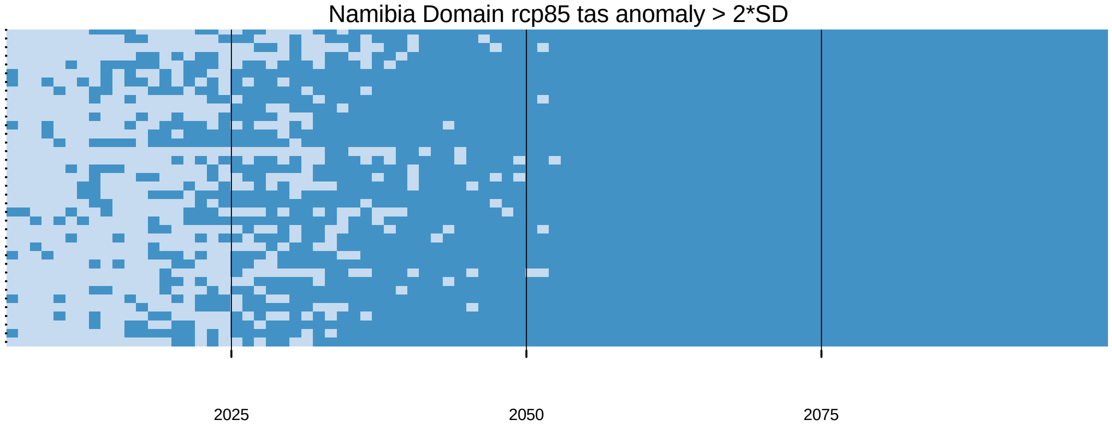
A



B



C



D

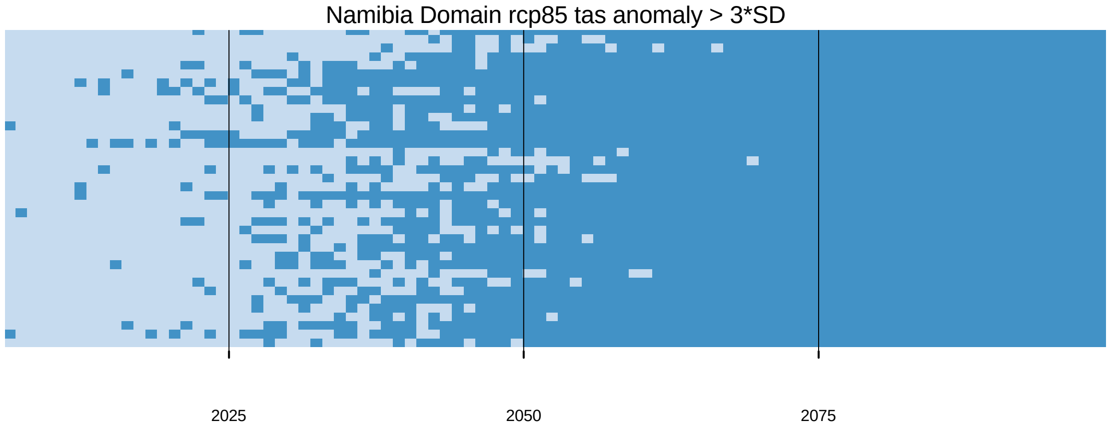
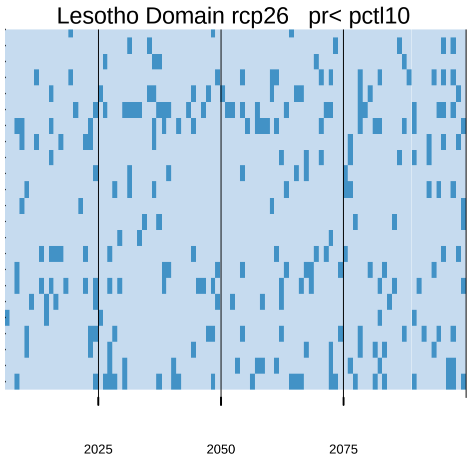


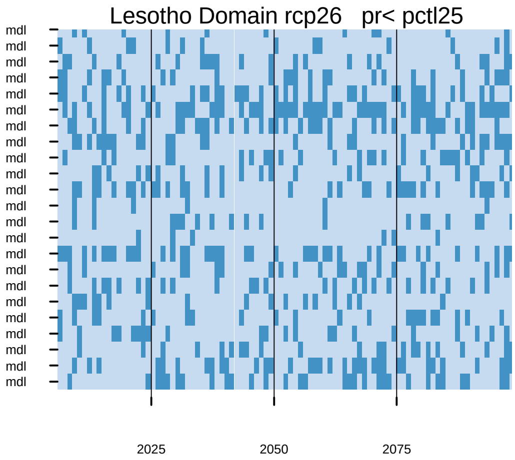
Figure 9. Distributions of projections in time for all individual models within CMIP5 for the Namibia Domain for which the mean annual temperature as compared to that for those during the base period of 1986-2005 exceeds: A 2 standard deviations under RCP2.6; B 3 standard deviations under RCP2.6; C 2 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.

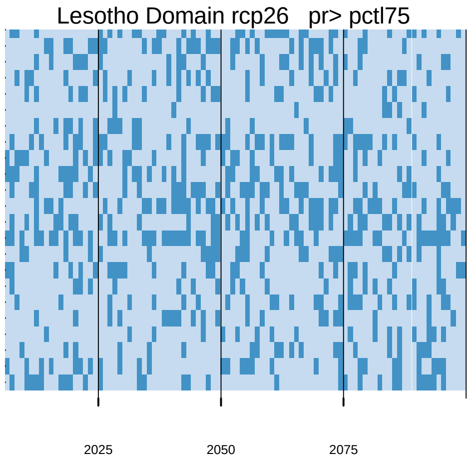
Note that the presentation in Figure 9, for which the years in excess of two or three standard deviations have been identified individually, differs from that in the IAV statistics, for which sequences of two and three years above the two standard deviations levels have been employed. From A and B in Figure 9, for RCP2.6, it is clear that some models develop future annual temperatures above the thresholds quickly and persistently whereas others produce few during the century. A similar observation may be applied to C and D in Figure 9, 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 9 is the disparate extents to which the formulations of the various models respond to increased concentrations of atmospheric CO_2.

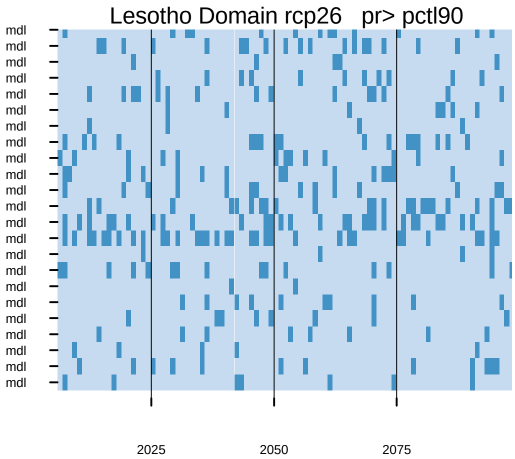
Equivalent results for rainfall and for RLE over the Lesotho Domain under RCP2.6 and RCP8.5 are shown in Figures 10 and 11.

A


Lesotho Domain rcp26 pr< pctl10
2025
2050
2075


Lesotho Domain rcp26 pr< pctl25
mdl
2025
2050
2075


Lesotho Domain rcp26 pr> pctl75
2025
2050
2075


Lesotho Domain rcp26 pr> pctl90
mdl
2025
2050
2075

B

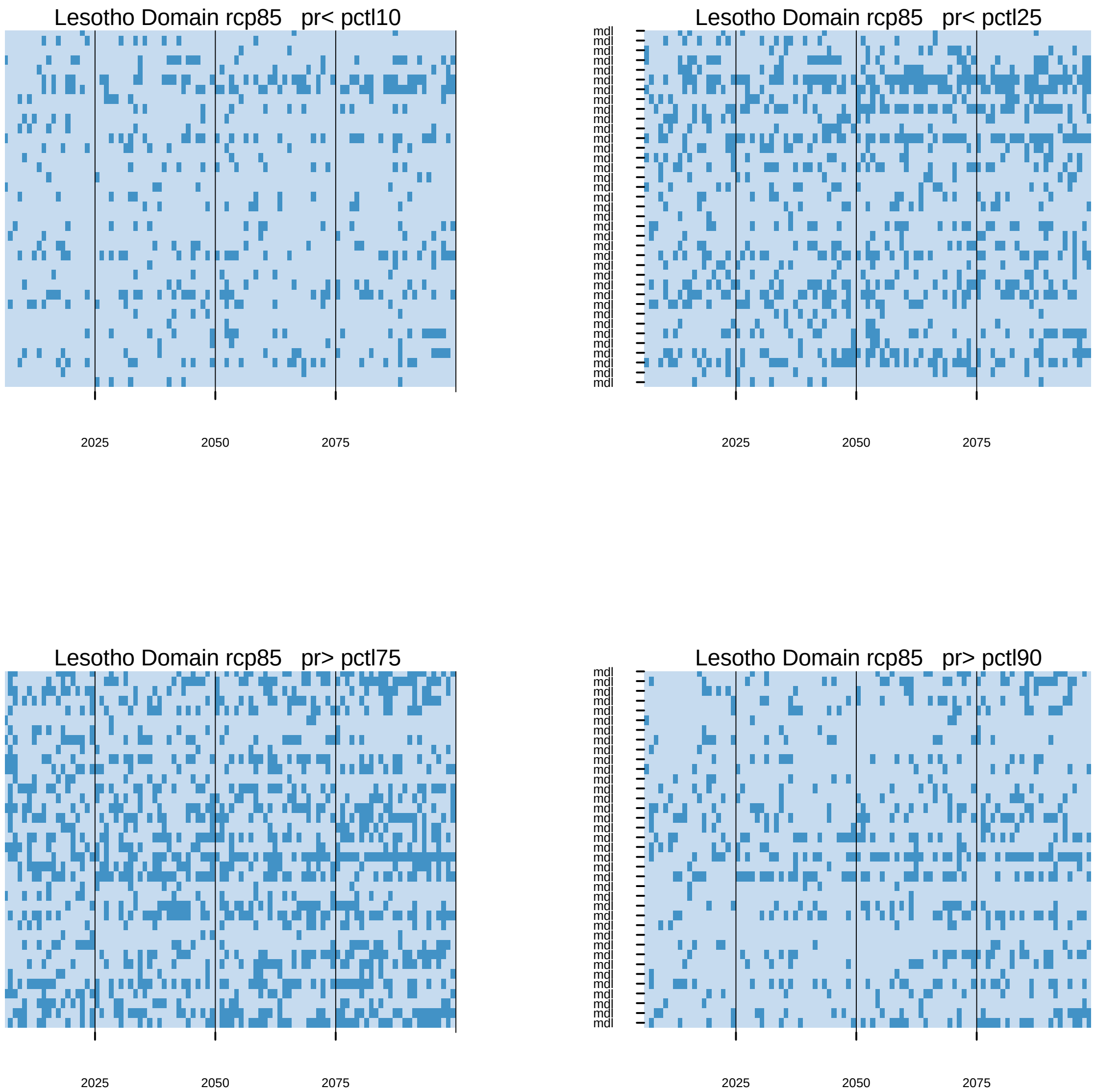
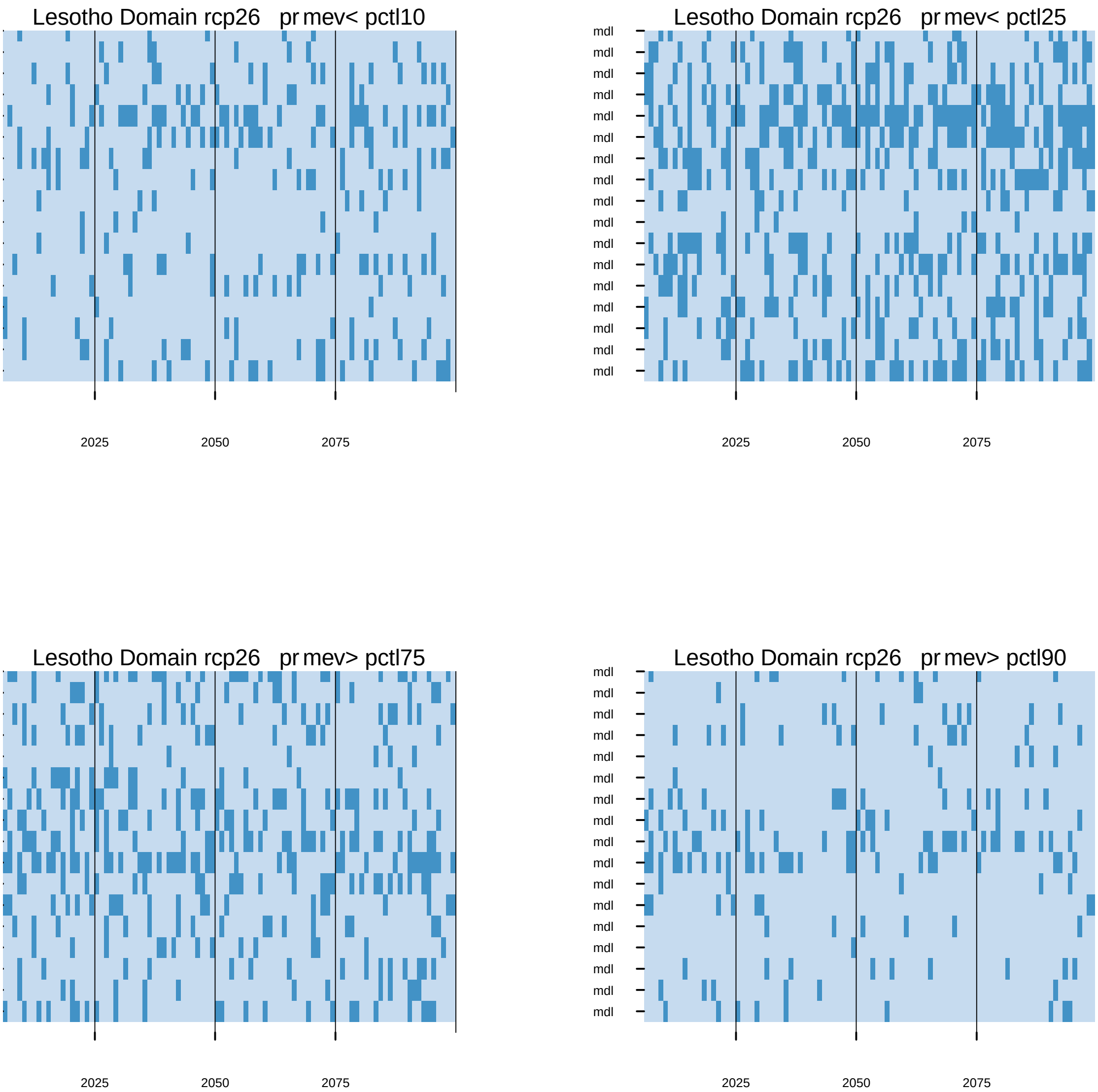


Figure 10. Similar to Figure 9 but for rainfall over the Lesotho Domain. A: under RCP2.6. B: under RCP8.5. In both A and B the top left hand chart indicates occasions when each model (each row covers a projection for each model separately) simulates annual (*not* two-or three-year totals) below the 10^{th}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


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

A

B

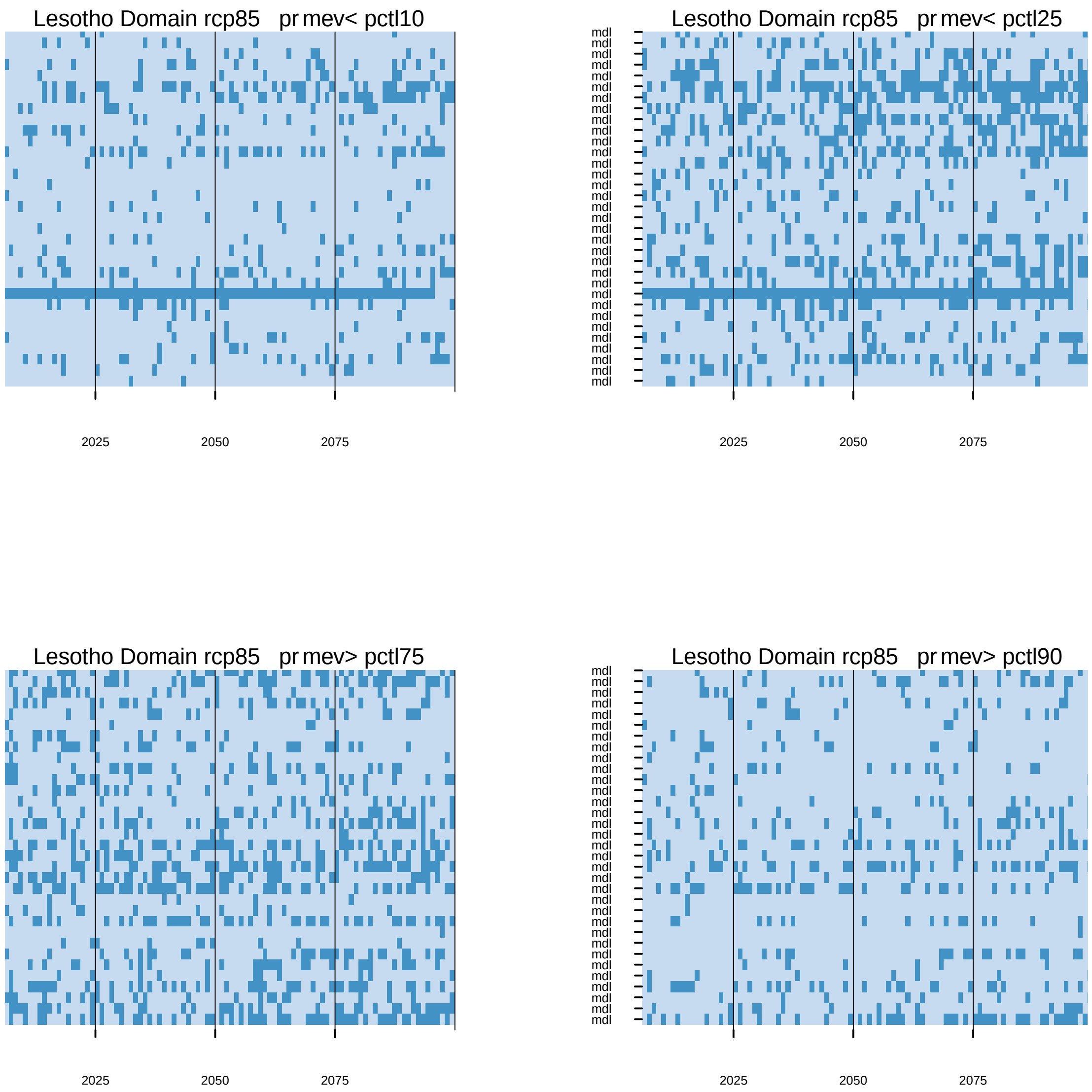


Figure 11. As Figure 10 but for rainfall less evaporation. The solid lines on the charts for below the 10th and 25th percentiles for projections from a single model may indicate an issue with projections from this model.

Probably the immediate observations from Figures 10 and 11 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 9, 10 and 11 are available on request for all Domains and all RCPs.

For the Lesotho and Vaal Domains future likelihoods of two- and three- years periods with rainfall totals outside the 10th and 90th percentiles change little through the century. However, those outside the 25th and 75th percentiles both increase although, allowing for the noise inherent in these calculations, not least in the relatively-lightly populated RCP2.6 and RCP4.5, there is no clear signal in terms of changing RCP. Nevertheless, the results suggest increasing likelihoods of extended periods of both lighter and heavier rainfalls than in recent years, and thus an increasing spread of values of annual totals. Equivalent conclusions may be drawn from the RLE IAV calculations.

Further west, in the Confluence and Namibia Domains, the signal is definitely for decreasing rainfall, with diminishing prospects of extended periods above the 75th and 90th percentiles and increasing prospects below the 25th and 10th percentiles, with a possible signal that the drier conditions may be exacerbated with higher RCPs. In neither of these Domains are the rainfall IAV results replicated in the RLE calculations. For Namibia the background distributions of annual RLE are skewed such that, apart from clear signals of diminishing heavier rainfall, no clear conclusions may be drawn. Over the Confluence Domain, on the other hand, the calculations point to an intriguing situation in which there is limited future change in the distributions of rainfall less evaporation, presumably through near-compensation of changes in one by changes in the other. Some possible reasons for this are outlined in the Conclusions section and point to a need for care in using this result.

5 Conclusions

In an earlier report to CRIDF three previous sets of climate change scenarios for the Orange-Senqu Basin, or parts of it, have been reviewed:

1. D. Knoesen, R. Schulze, C. Pringle, M. Summerton, C. Dickens and R. Kinz; 2009: Water for the Future: Impacts of Climate Change on Water Resources in the Orange-Sengu River Basin
2. S. Crerar, J. Volkholz and J. Lutz; 2011: Projection of Impacts under Plausible Scenarios and Guidelines on Climate Change Adaptation Strategies
3. World Bank: 2016: Lesotho Water Security and Climate Change Assessment

Using the identifying numbers from the list above:

1. Used multiple outputs from a single numerical climate model under a single, high emissions scenario to produce an extensive information base on which to plan but, despite recognition of the issue, the judgement in the review was that uncertainties were handled weakly. The main results were:
   Temperature: increases by 2.5-3.5ºC in 2046-2065, then by >5ºC (diagrams suggest >7ºC) by 2081-2100
   Evaporation: increases by 10-15% then 20-25%
   Rainfall: increases by 20%, then by 20-100%
   Rain days >10mm: increase by 10-20%, then 30-100%
   Short duration rainfall (<24hr): in 2046-2065 40% of basin has an increase, 38% a decrease; in 2081-2100 72% has an increase
   Long-duration rainfall (1 and 7 days): with 10-year return period much of basin sees increase for 1 day but decrease for 7 days; with 2-year return period increases

2. Used both a single statistical climate model and a single numerical climate model under a single, high emissions scenario, but indicated that the precipitation downscaling from the numerical model was unsatisfactory and was judged to have a weak handling of uncertainties. The main results were:
   Temperature: all areas see increase with annual maximum over Kalahari – 2.5-2.6ºC by STARII and 2.3ºC by CCLM; distribution of seasonal increases (STARII only) varies substantially between each season
   Rainfall: for lowest 5% realisation, overall decrease of 140mm (with increases over SE Lesotho); for median decreases of 60mm (with increases over SE Lesotho); for highest 5% decreases of 80 mm (with increases over E Lesotho)

3. Used many CMIP3 and CMIP5 downscaled (by two methods) projections under a range of emissions scenarios (all higher than RCP2.6) entered into a single hydrological model over Lesotho. Strengths of the report were judged to include use of multiple models and detailed coverage of uncertainties; the weakness was the unrestricted combination of models from different eras, plus elimination of certain models for unspecified reasons, probably resulting in biases. The main results were:
   All projections give increased temperatures in range 0.8-2.9ºC, but precipitation projections distributed roughly between ±20%. Trend analysis suggested warming of 2ºC to 1980-2003 but inhomogeneity in data set at 2003. These results also suggested:
   - Frost days decreased
   - Diurnal temperature range decreased
   - Growing season lengthened
   - Wet days (>1mm) weakly increased

Reports 1 and 2 return diagrammatically opposed results in terms of future rainfall changes and, being based on single models, will not be considered further here. Report 3 is more comparable to the current report in its use of ensembles and several emissions scenarios (A2, A1B and B1 with CMIP3; RCP4.5 and RCP8.5 with CMIP5). Hence a subjective comparison of results in the two reports suggests that in relation to the current report:

- The temperature range suggested in Report 3 does not cover the full possible range as indicated in this current report
- The possibility of future rainfall changes lying in the range ±20% is reasonably consistent with results in this current report, although the recommended extreme scenarios suggest possible larger departures in either direction
- Decrease in frost days not examined in this current report but consistent with likely temperature trends
- Diurnal temperature range not considered in this current report, but the result is consistent with that in the IPCC AR5
- Growing season length not considered in this current report but could be addressed through further analyses
- Wet days increasing cannot be compared with results in this current report, and cannot be indicated to be inconsistent; however, reference has been made to earlier similar analyses using soms when examination of the IPCC 'extremes' for daily rainfall totals has indicated a high degree of noise resulting from disparate results across the CMIP5 projections.

Perhaps the critical considerations revealed in the current report, and perhaps not realised to a similar degree in Report 3, 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 are likely greatest across the Confluence Domain and least in the higher reaches of the two eastern Domains. Future distributions of temperature rises from the IAV (inter-annual variability) assessments are 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. For rainfall likelihoods of decreasing future annual amounts increase over the two western as compared to the two eastern Domains:

- For both the Lesotho Domain and the Vaal Domain there are distinct possibilities that rainfall may not decline, and may perhaps increase, thus protecting the inflow into the Basin from the headwaters. Nevertheless, some of the recommended scenarios, and not least the extreme scenarios, for these two Domains point strongly to a need to consider future reductions in rainfall in planning. The IAV analyses for rainfall point to a possibly increased spread in annual rainfall totals over both Domains but with little change in the frequencies of the unusually wetter and drier years
- For the Confluence Domain the more optimistic of the recommended scenarios, albeit with only a 25% assessed likelihood, is for current levels of rainfall to be maintained, with an increase suggested in the appropriate extreme scenario. However the weight of evidence is for a future decrease of about 10% in the recommended scenario or 20% in the extreme scenario. The IAV analyses indicate moves towards a drier future climate.
- Over the Namibia Domain both recommended scenarios include reduced rainfall, by about 15% in the most likely (90% as assessed), perhaps 30% in the other and in the extreme scenario; a second extreme scenario offers limited hope of a 10% increase. The IAV analyses indicate moves towards a drier future climate.

Conclusions drawn from the soms that assessed temperature against RLE (rainfall less evaporation) do not necessarily replicate the results as immediately above for temperature against rainfall, although the results for temperature alone are similar and are not discussed further below. Differences that emerge between rainfall and RLE may result from a number of sources:

- Both rainfall and evaporation are complex to simulate in global climate models, not least because the resolution of these models does not permit identification of the individual thunderstorms, or clusters of them, that provide most of the rainfall in the Basin, and various approaches have been employed in the different models that produce a spectrum of results[3] (as suggested, as summarised earlier, in the IPCC 'extremes' values)
- The simulation of evaporation depends in part on that of rainfall, as well as on a number of other issues, all of which introduce perturbations into the projections
- The issues above ripple into the simulation of both rainfall and evaporation across the base period of 1986-2005 (to a potentially greater extent than for rainfall alone), perhaps with the result of generating a non-Gaussian climatology on which to base the soms and IAV results, something that is most likely to have affected results from the Confluence and Namibia Domains.

Given the qualifiers above, then for RLE:

- Over the Lesotho Domain the recommended scenario with highest likelihood (suggested as 55%) includes a reduction in RLE of around 15%, which, if it occurs, would be detrimental to water input into the Basin – note that this is inconsistent with the conclusion from rainfall alone, but the distinctions in likelihoods are perhaps insignificant; there is a wide spread of about +35% to -55% in the extreme scenarios. The IAV analyses for RLE point to a possible increased spread in annual rainfall totals but with little change in the frequencies of unusually wetter and drier years
- Over the Vaal Domain likelihoods of RLE changes of approximately ±10% are roughly equal in the recommended scenarios, a result that is perhaps not inconsistent with that for rainfall; the extreme scenarios cover a range of ±30%. The IAV analyses for RLE point to a possible increased spread in annual rainfall totals but with little change in the frequencies of unusually wetter and drier years
- There is a weighting towards reduced RLE over the Confluence Domain, although the likelihood as estimated is about 60%, with a 10% increase or a 30% decrease in the extreme scenarios. However, the IAV results for RLE suggest a possible continuation of current conditions of the balance between rainfall and evaporation, with the caveat that this result may emerge from the statistics of the background climatology as outlined above.
- For the Namibia Domain results suggest a possible increase of 60% in RLE in the recommended scenario with estimated likelihood of 40%, even 70% in the extreme scenario, but this is the Domain that appears to be most affected by the issues re base period climatologies introduced above, and thus should be approached with appropriate caution. Care needs to be taken in interpreting the IAV results for this Domain; the best that can be said is that there may be future decreases in the frequencies of the heavier rainfall events.

3 Note that even were the resolution of the models to be increased sufficiently to resolve these storms other technical issues might mitigate against a substantial reduction in associated uncertainties.

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[4] 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[5].

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 Relative 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

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

5 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.

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 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.

Appendix 2. An introduction to the interpretation of self-organising maps 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.

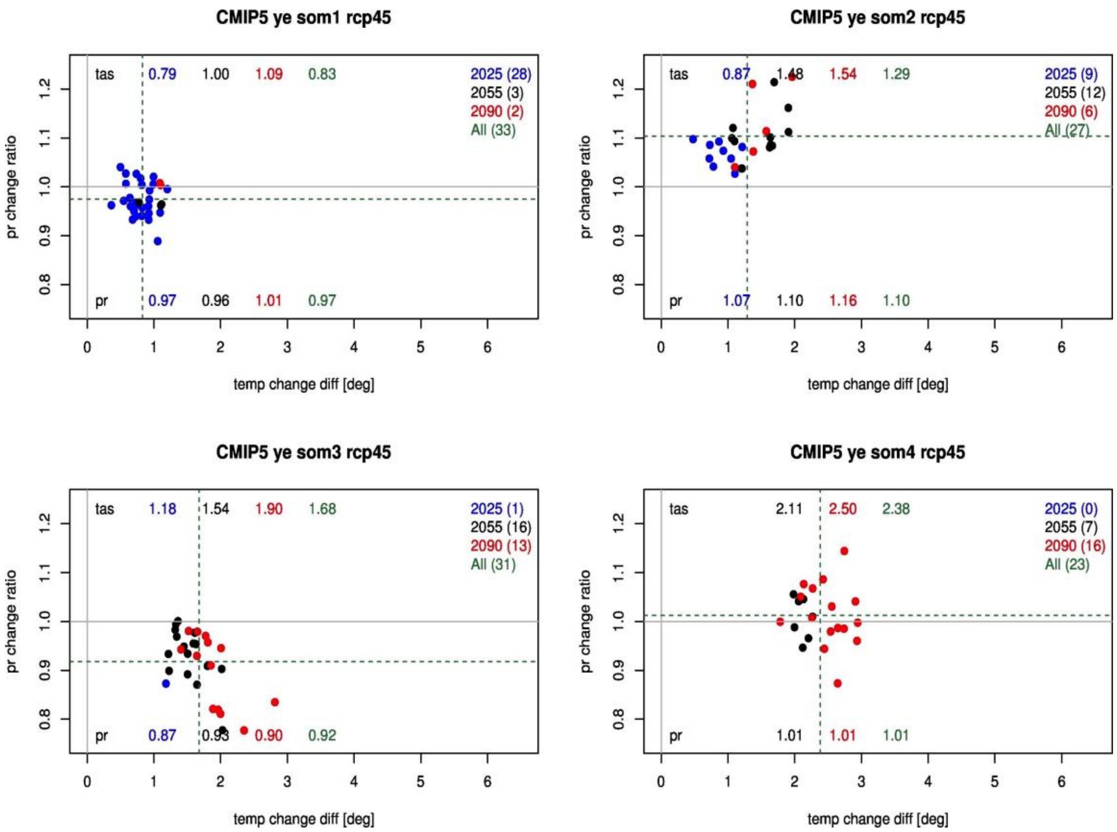


Figure 12. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the full rainfall season (Nov to Apr) under RCP4.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents 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 Relative 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)	Global decision making; economic growth priority
A1T (technology-based generation)	
A1B (balanced between fossil fuels and technology)	
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 Lesotho Domain

Introduction. Results are presented below for the analyses through self-organising models (soms) for the Lesotho 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; a limited number of rainfall less evaporation projections have been eliminated subjectively from the analyses where over-large changes in rainfall less evaporation results because of near-zero rainfall less evaporation values during the base period of 1986-2005.

Also provided towards the end of this document are results for the inter-annual variability (IAV) calculations, in all cases located immediately after the soms charts to which they refer. 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 1986-2005. 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.

Summary of results. For all RCPs there are suggestions that the topography of the Lesotho Domain has created issues for the models in simulating rainfall, and perhaps most so for RCP2.6 and RCP6.0, although the relatively small number of projections must be an issue in these two cases also.

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, with a clear weighting towards an increase, or at least little change from current conditions, in all except RCP8.5, for which the likelihoods of increase/decrease are similar.

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 1986-2005 increase, naturally, with RCP, but vary also according to individual soms. Under RCP8.5 successive two- and three-year periods are almost certain by the 2050's for two standard deviations and by the 2060's for three standard deviations. By contrast, under RCP2.6 only one of the soms produces 100% probabilities (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.

Likelihoods of annual rainfall totals outside the 10th and 90th percentiles over 2 and 3 years do not change substantially with RCP, in general being below 10%. Nor does there seem to be much change in likelihoods for both in time, although perhaps these increase a little later in the century, particularly in RCP8.5. Likelihoods of 2/3 year rainfall totals outside the 25th and 75th percentiles do tend to increase in the later century, particularly for the higher 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 RCP2.6 there is a distinct bias towards future drier conditions, with an estimate of a 75% likelihood of drier conditions in some form. For the remaining RCPs there is roughly a 50-50 split in likelihoods between drier and 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 but it is not particularly marked.

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 increased above there towards the end of the century for the higher RCPs. However, there are increasing likelihoods of 2/3 year values outside the 25th and 75th percentiles as the century proceeds, again especially for RCP6.0 and RCP8.5. 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 Lesotho sits at a location approximately where there is a geographical divide between increases and decreases both for projected rainfall and for projected rainfall less evaporation in most ensemble means, and these soms results appear consistent with that, with rough equality overall towards increases and decreases in the suggested scenarios.

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. It suggests approximately similar prospects of increased and decreased water availability in both analyses but with slightly higher likelihood for an increase in the temperature vs rainfall assessment and for a decrease in the temperature vs rainfall less evaporation assessment. These differences in likelihoods 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 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 Lesotho Domain based on RCP2.6, RCP4.5 and RCP6.0

Recommended scenarios based on temperature against rainfall analyses

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

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	2.25ºC/1.10
Decreased	1.25ºC/0.90	1.50ºC/0.90	2.25ºC/0.85

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
55	1.00ºC/0.90	1.75ºC/0.85	2.25ºC/0.80
45	1.00ºC/1.20	1.50ºC/1.20	1.75ºC/1.20

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

	2040	2065	2080
Increased	1.00ºC/1.20	1.25ºC/1.35	1.75ºC/1.40
Decreased	1.25ºC/0.60	1.75ºC/0.55	2.25ºC/0.50

Recommended Scenarios for the Lesotho Domain based on RCP8.5

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
50	1.50ºC/1.05	2.75ºC/1.05	4.25ºC/1.05
50	1.50ºC/0.95	2.75ºC/0.95	4.25ºC/0.95

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

	2040	2065	2080
Increased	1.00ºC/1.10	3.00ºC/1.15	3.50ºC/1.20
Decreased	1.50ºC/0.90	3.00ºC/0.85	4.50ºC/0.80

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
55	1.25ºC/1.30	2.75ºC/1.20	4.25ºC/1.25
45	1.50ºC/0.90	3.00ºC/0.75	4.50ºC/0.65

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

	2040	2065	2080
Increased	1.25ºC/1.40	2.75ºC/1.50	4.00ºC/1.70
Decreased	1.50ºC/0.50	3.00ºC/0.50	4.50ºC/0.50

Scenarios from each RCP for the Lesotho 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	60	2→3	1.25°C/1.00	1.50°C/0.95	1.50°C/1.00		**45**	1	1.00°C/0.90	1.00°C/0.90	1.00°C/0.90
2	25	4	0.75°C/1.05	0.75°C/1.05	0.75°C/1.05		**25**	3	0.75°C/1.20	0.75°C/1.20	0.75°C/1.20
3	15	1	0.75°C/0.95	0.75°C/0.95	0.75°C/0.95		**15**	1→2	1.00°C/0.90	1.75°C/0.85	1.75°C/0.90
4							**15**	1→4	1.00°C/0.90	1.50°C/0.65	1.50°C/0.65

Summary: Easiest to interpret by contrasting TR and TRLE in terms of future temperatures. For those scenarios with steady or increased temperatures (Line 1, 60%, in TR and Lines 1, 3 and 4, 75%, in TRLE) rainfall or rainfall less evaporation tend to decrease on the whole; the suggestion is that there is a greater drop in water availability in these scenarios when increased temperatures are taken into consideration. The cooler scenarios are split in TR in terms of water availability (Lines 2 and 3, 40%, but availability increases in TRLE (Line 2, 25%). As the higher likelihood in TR of these latter two (Line 2, 25%; Line 3 15%) is for increased water availability, the overriding picture is for higher likelihood for relatively greater temperature increases combined with decreased water availability, and *vive versa* for lower likelihood.

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	1.00°C/1.10	1.00°C/1.10	1.00°C/1.10		1.00°C/1.20	1.25°C/1.30	1.00°C/1.30
Decreased	1.00°C/0.90	1.00°C/0.90	1.00°C/0.95		1.00°C/0.60	1.50°C/0.60	1.50°C/0.60

RCP4.5 – 38 and 32 projections

	%		2040	2065	2080		%		2040	2065	2080
1	60	1→4	1.00°C/1.00	2.00°C/1.00	2.50°C/1.05		25	2→4	1.25°C/0.90	2.25°C/0.85	2.50°C/0.90
2	25	2	1.25°C/0.95	1.75°C/0.95	2.00°C/0.95		25	2→3	1.25°C/0.90	1.75°C/0.80	1.75°C/0.85
3	15	3	1.25°C/1.10	1.50°C/1.05	1.50°C/1.05		25	1	1.00°C/1.20	1.50°C/1.20	1.50°C/1.25
4							25	1→4	1.00°C/1.20	1.75°C/1.20	2.00°C/1.25

Summary: In TRLE There is a split between decreased water availability (Lines 1 and 2, both 25%) and increased availability (Lines 3 and 4, both 25%), although there is no clear link with relative temperature increases. In TR there is perhaps an increase in rainfall with the strongest and lowest temperature increases (Line 1, 60%, and Line 3, 15%, respectively), while rainfall decreases are associated with a middle-of-the-road scenarios (Line 2, 25%).

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/1.10	1.75ºC/1.15	2.75ºC/1.10		1.25ºC/1.30	1.25ºC/1.40	2.50ºC/1.40
Decreased	1.75ºC/0.90	2.00ºC/0.85	2.50ºC/0.85		1.75ºC/0.60	2.50ºC/0.50	3.00ºC/0.50

RCP6.0 – 15 and 12 projections

	%		2040	2065	2080		%		2040	2065	2080
1	85	1→4→3	1.00ºC/1.00	1.50ºC/1.05	2.25ºC/1.05		50	2→3	1.00ºC/1.35	1.50ºC/1.20	2.25ºC/1.05
2	15	1→2	1.00ºC/1.00	1.50ºC/0.95	2.50ºC/0.85		50	1→4	1.00ºC/0.90	1.50ºC/0.80	2.50ºC/0.50

Summary: Both TR and TRLE are split into increased and decreased water availability with the former associated with slightly lesser temperature increases. One difference is that the two scenarios are roughly equally likely in TRLE whereas in TR the cooler/wetter scenario is more prominent (Line 1, 85%).

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/1.10	1.50ºC/1.10	2.00ºC/1.15		1.00ºC/1.30	1.50ºC/1.40	2.00ºC/1.40
Decreased	1.00ºC/0.90	1.75ºC/0.90	3.00ºC/0.90		1.00ºC/0.60	1.75ºC/0.50	3.00ºC/0.50

RCP8.5 – 40 and 33 projections

	%		2040	2065	2080		%		2040	2065	2080
1	50	1→3	1.50ºC/1.05	2.75ºC/1.05	4.25ºC/1.05		55	1→4	1.25ºC/1.30	2.75ºC/1.20	4.25ºC/1.25
2	50	2→4	1.50ºC/0.95	2.75ºC/0.95	4.25ºC/0.95		45	2→3	1.50ºC/0.90	3.00ºC/0.75	4.50ºC/0.65

Summary: As for RCP6.0 both TR and TRLE are split into increased and decreased water availability with the former associated with slightly lesser temperature increases in TLRE but similar ones in TR. In TR the two suggested scenarios are roughly equally likely whereas in TRLE the cooler/wetter scenario is more prominent (Line 1, 55%).

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	1.00ºC/1.10	3.00ºC/1.15	3.50ºC/1.20		1.25ºC/1.40	2.75ºC/1.50	4.00ºC/1.70
Decreased	1.50ºC/0.90	3.00ºC/0.85	4.50ºC/0.80		1.50ºC/0.50	3.00ºC/0.50	4.50ºC/0.50

RCP2.6; temperature vs rainfall

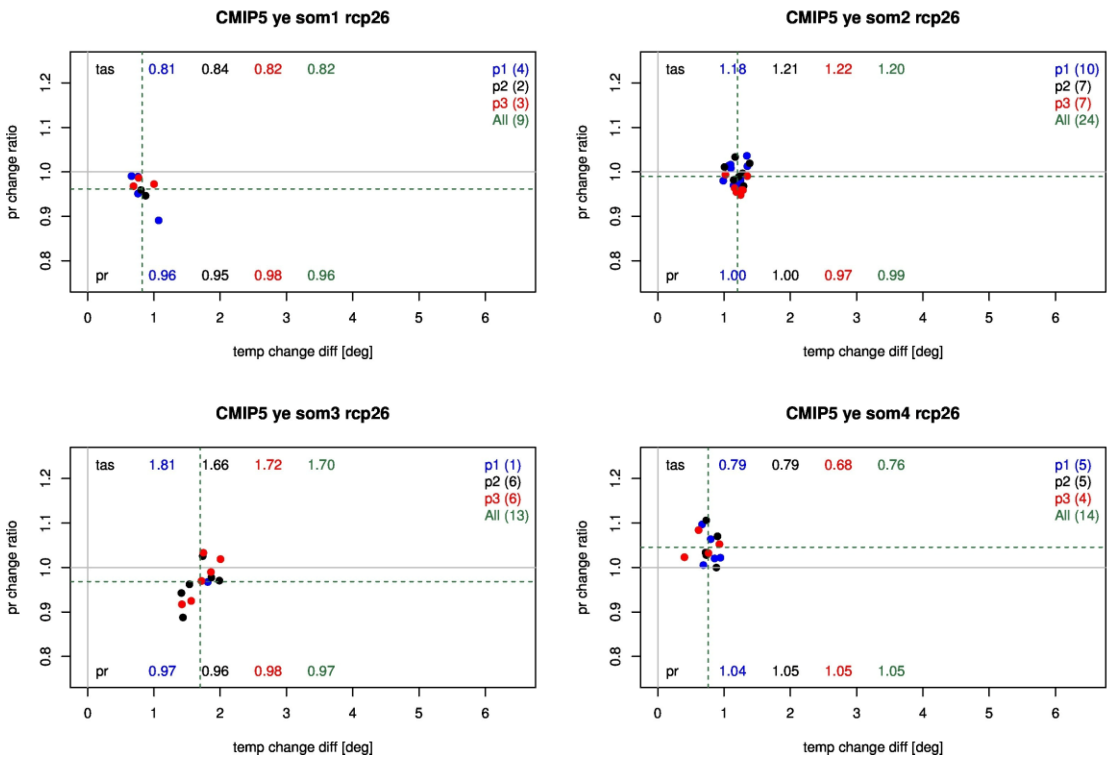


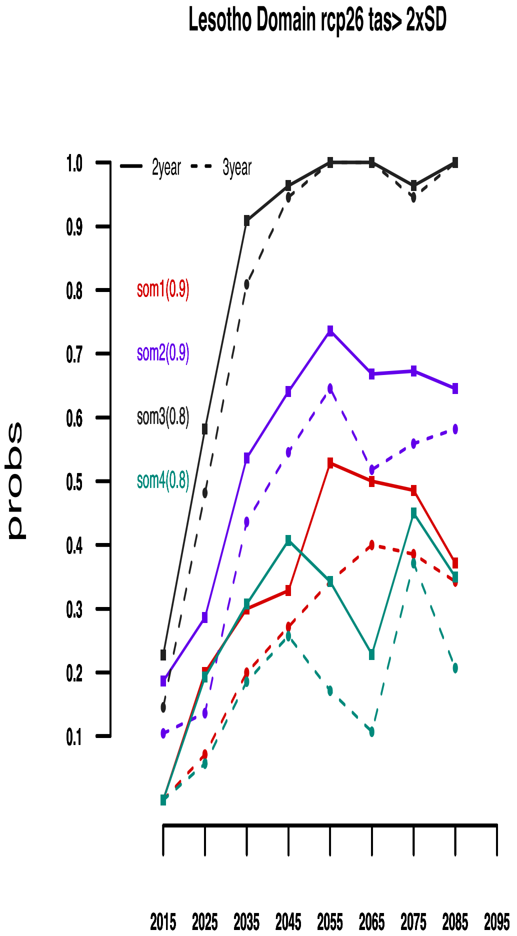
Figure LD13. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Lesotho Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 LD1a. Scenarios for the year over the Lesotho Domain under RCP2.6 based on Figure LD1 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	2→3	1.25ºC/1.00	1.50ºC/0.95	1.50ºC/1.00
25	4	0.75ºC/1.05	0.75ºC/1.05	0.75ºC/1.05
15	1	0.75ºC/0.95	0.75ºC/0.95	0.75ºC/0.95

Summary: One som, number 4, with a clear increase in rainfall of about 5%. The three remaining soms, mostly indicating reduced rainfall, have been split into two pathways, a dominant one from som2 and som3, and a lesser likelihood one in som1. The reason for the split is the notably lower temperature increase in som1.

RCP2.6; temperature vs rainfall



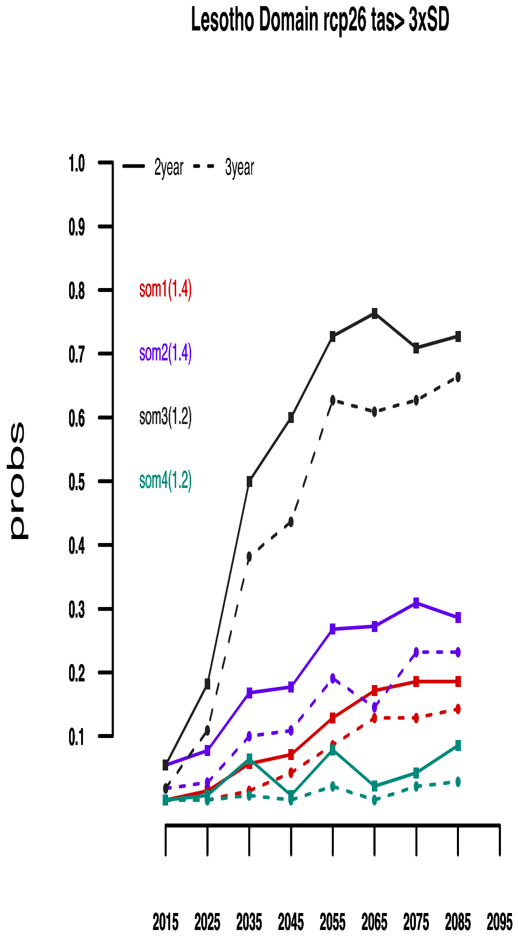


Figure LD14. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD1 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

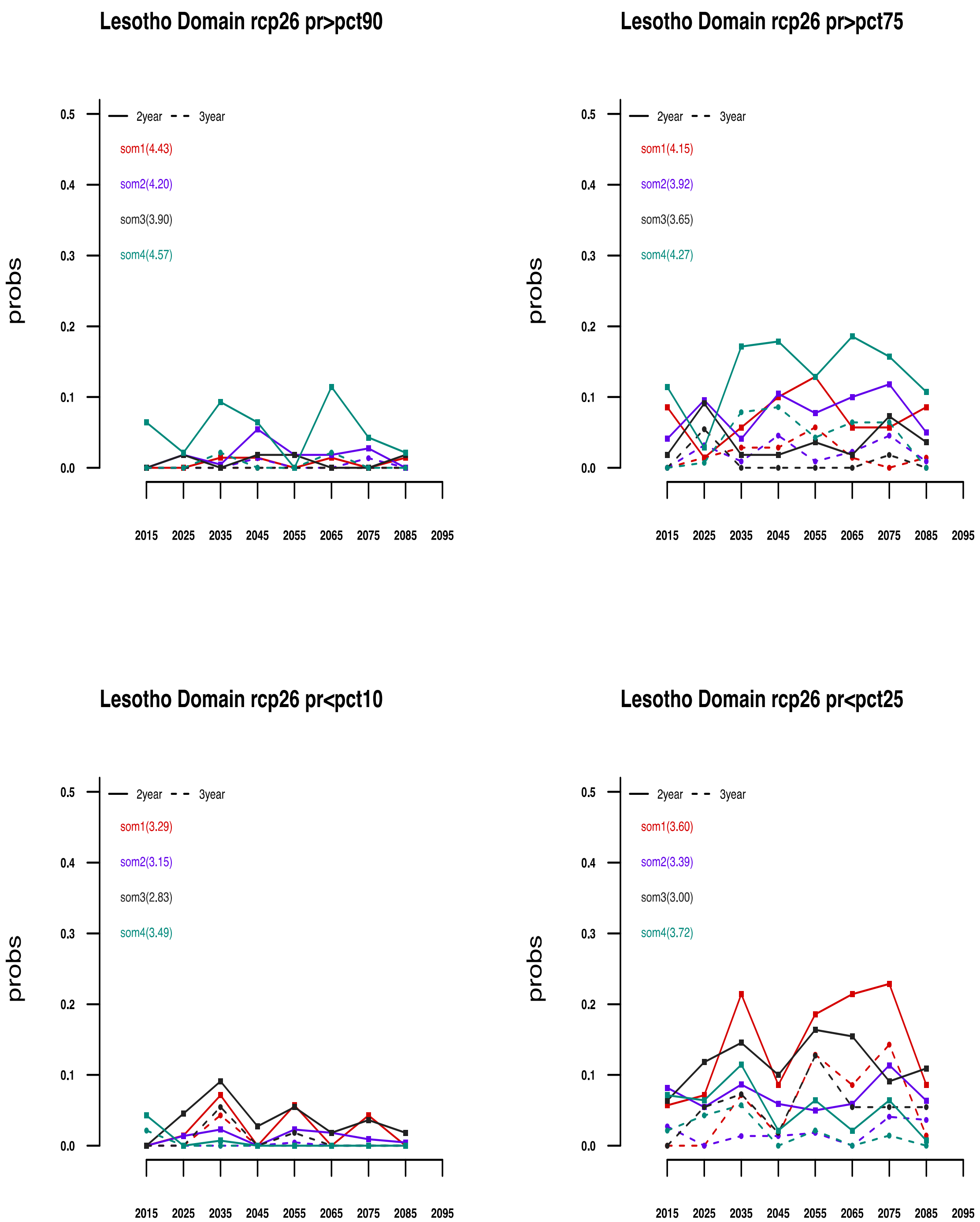


Figure LD15. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD1 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

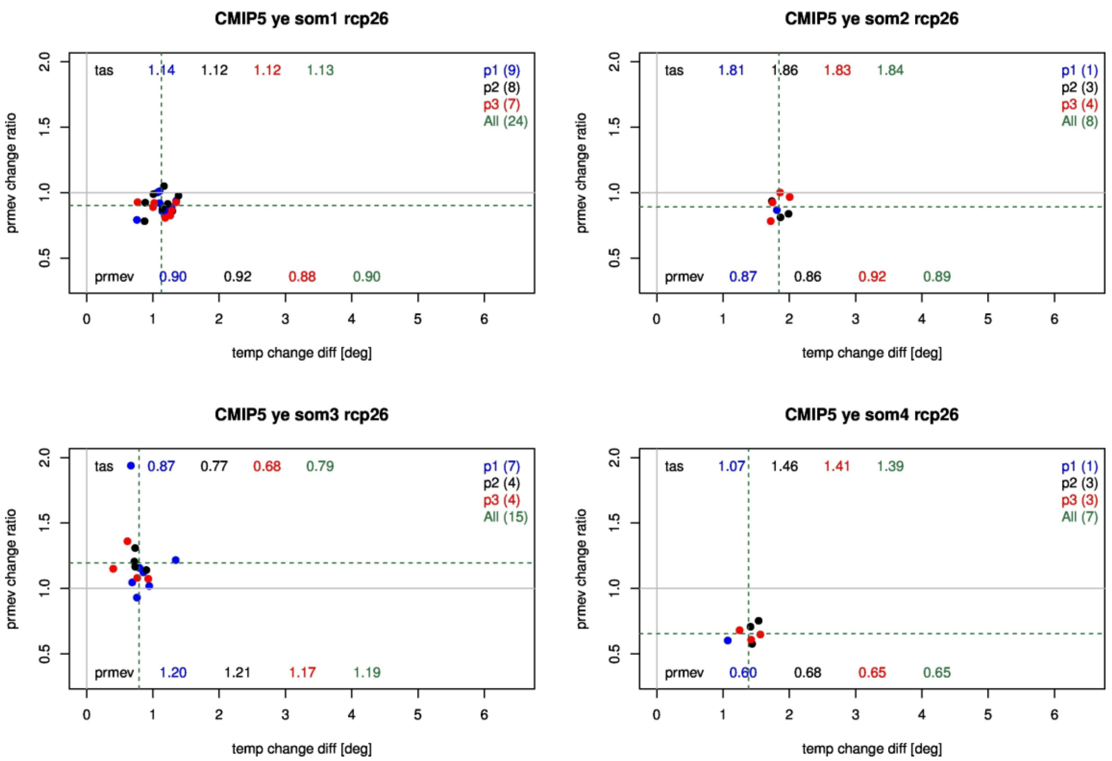


Figure LD4. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Lesotho Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 LD2a. Scenarios for the year over the Lesotho Domain under RCP2.6 based on Figure LD4 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/0.90	1.00ºC/0.90	1.00ºC/0.90
25	3	0.75ºC/1.20	0.75ºC/1.20	0.75ºC/1.20
15	1→2	1.00ºC/0.90	1.75ºC/0.85	1.75ºC/0.90
15	1→4	1.00ºC/0.90	1.50ºC/0.65	1.50ºC/0.65

Summary: A complex set of soms, probably partly resulting from the relatively limited number of projections but perhaps also because of the complex terrain. One clear scenario (second in the table, som 3) has an increase in prmev, but note it has one projection suggesting almost a doubling in the 2040 period that is allowed for the in the appropriate scenario. All others suggest future decreases in precipitation less evaporation, with most in som1, but a couple of lower-likelihood options in som2 and som4 that we have bracketed with som1.

RCP2.6; temperature vs rainfall less evaporation

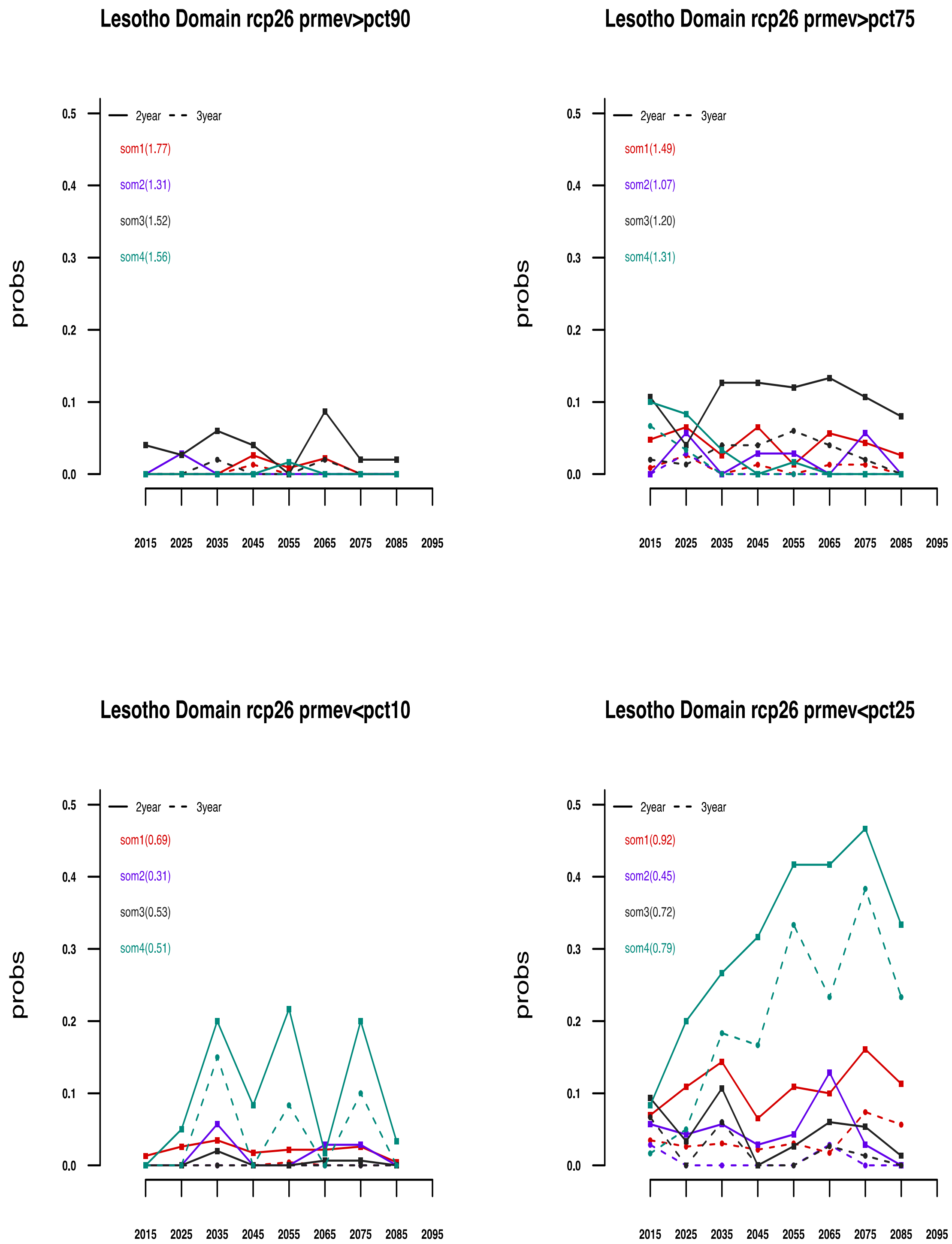


Figure LD16. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD3 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

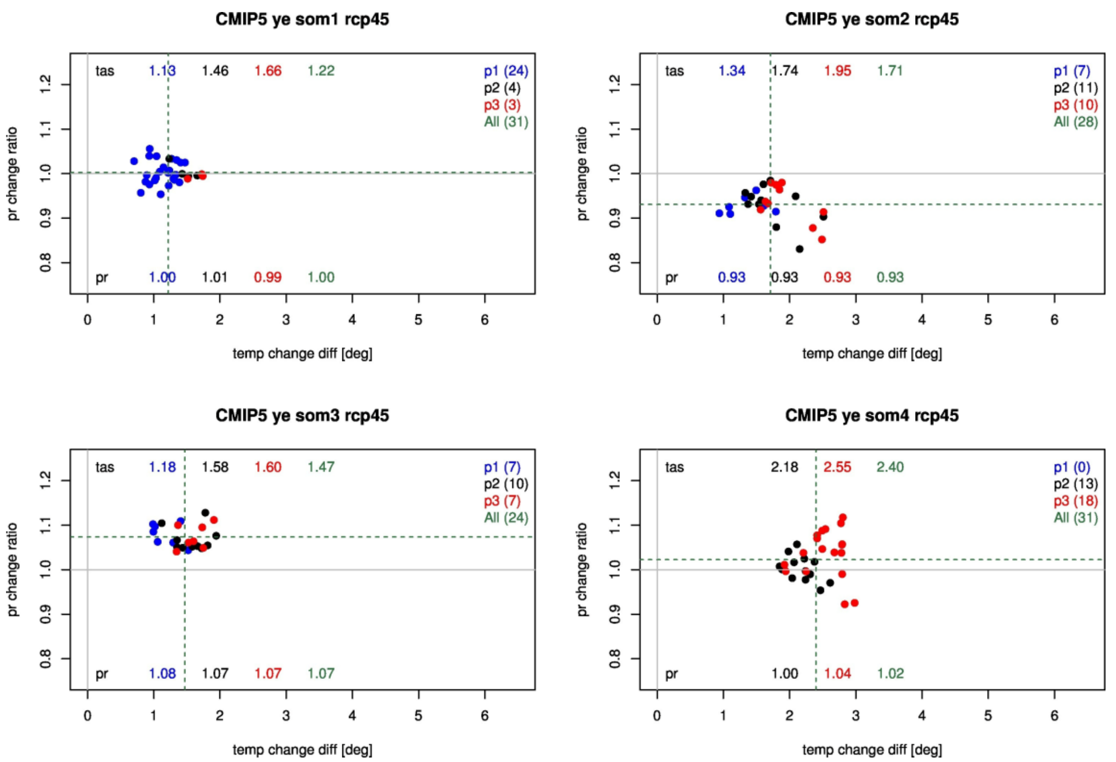


Figure LD6. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Lesotho Domain under RCP4.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 LD3a. Scenarios for the year over the Lesotho Domain under RCP4.5 based on Figure LD6 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→4	1.00ºC/1.00	2.00ºC/1.00	2.50ºC/1.05
25	2	1.25ºC/0.95	1.75ºC/0.95	2.00ºC/0.95
15	3	1.25ºC/1.10	1.50ºC/1.05	1.50ºC/1.05

Summary: At most about 5% differences in rainfall in all scenarios, with the highest likelihood one seeing little change.

RCP4.5; temperature vs rainfall

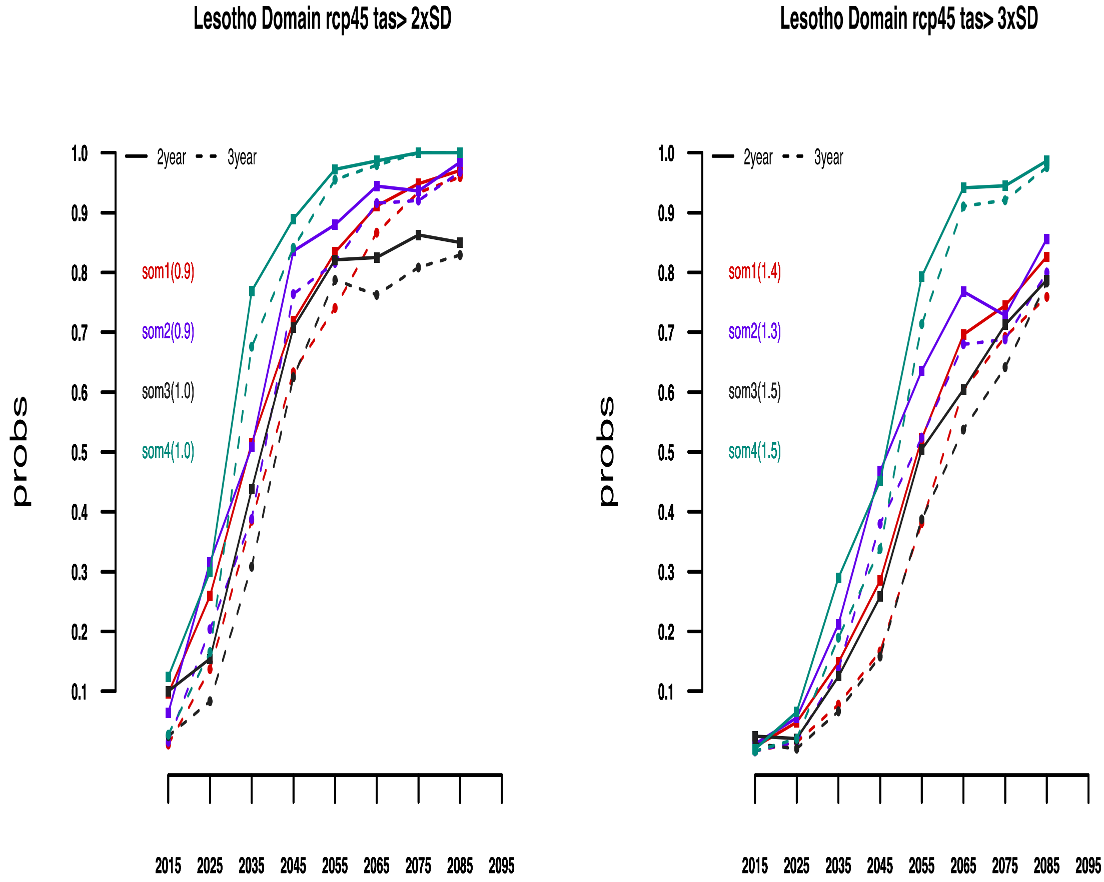


Figure LD7. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD6 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

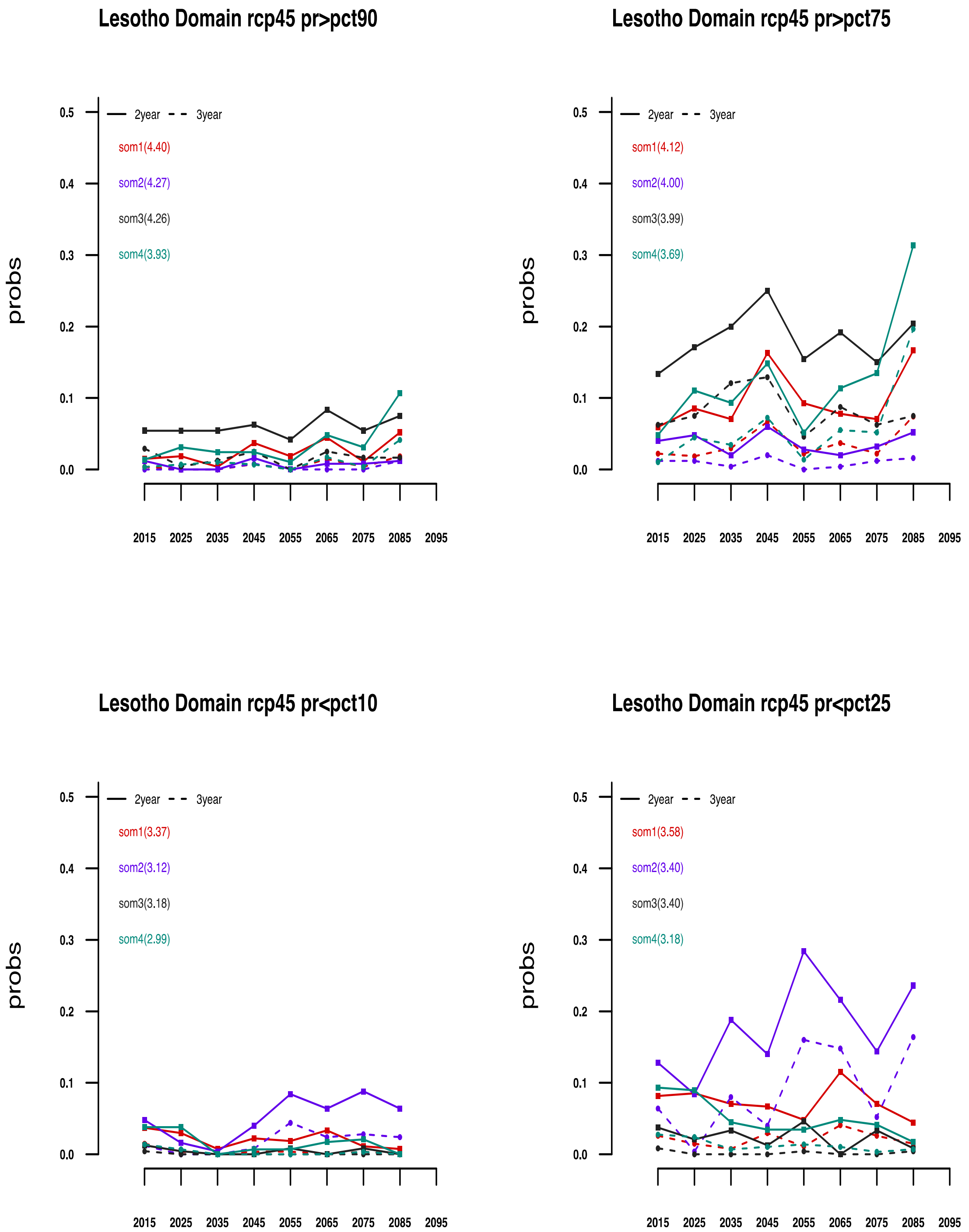


Figure LD8. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD6 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

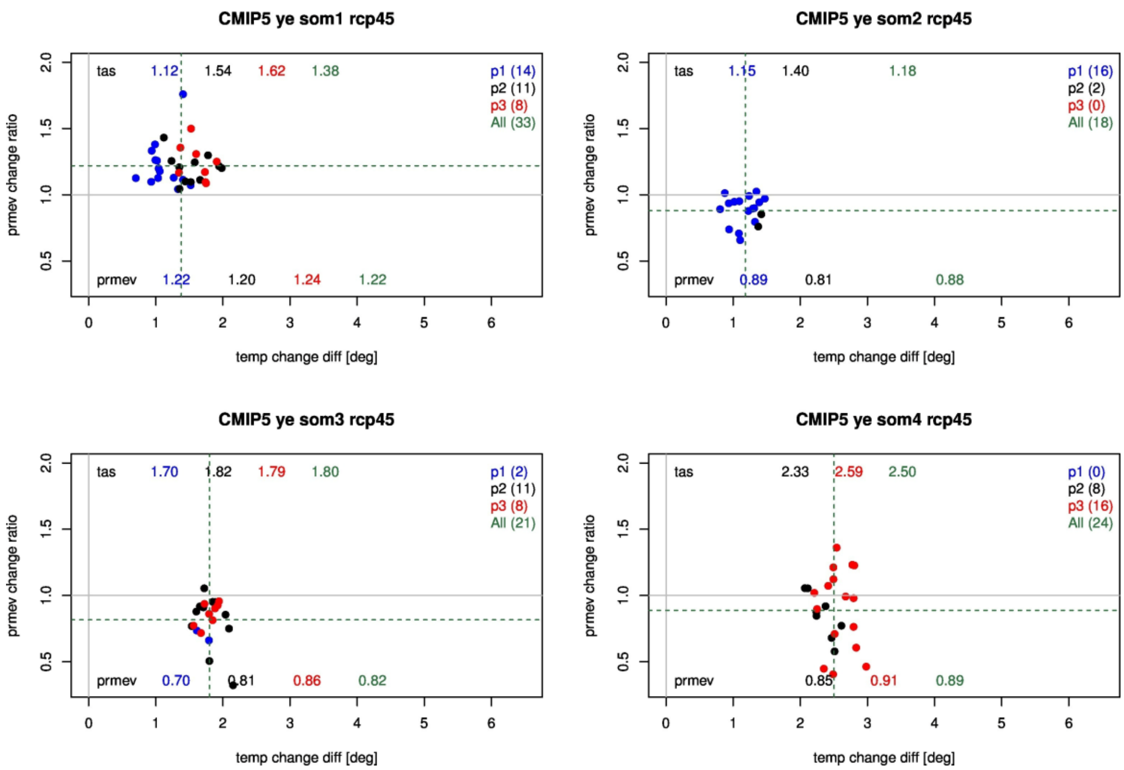


Figure LD9. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Lesotho Domain under RCP4.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 LD4a. Scenarios for the year over the Lesotho Domain under RCP4.5 based on Figure LD9 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
25	2→4	1.25ºC/0.90	2.25ºC/0.85	2.50ºC/0.90
25	2→3	1.25ºC/0.90	1.75ºC/0.80	1.75ºC/0.85
25	1	1.00ºC/1.20	1.50ºC/1.20	1.50ºC/1.25
25	1→4	1.00ºC/1.20	1.75ºC/1.20	2.00ºC/1.25

Summary: Basically two scenarios, a wetter one in som1 plus two drier ones that originate in som2. Note, however, the dispersion of prmev projections for p3 in som4, with a few projections suggesting relatively warm and moist conditions at this time. For the first time in analyses of this form it has been decided to split the values in som4, consistent in temperature but not in prmev, between the cooler/wetter scenarios and the warmer/drier scenarios. The result is roughly equal likelihoods for all four scenarios in the table above, and hence approximately 50% for future wetter conditions, and 50% for drier conditions.

RCP4.5; temperature vs rainfall less evaporation

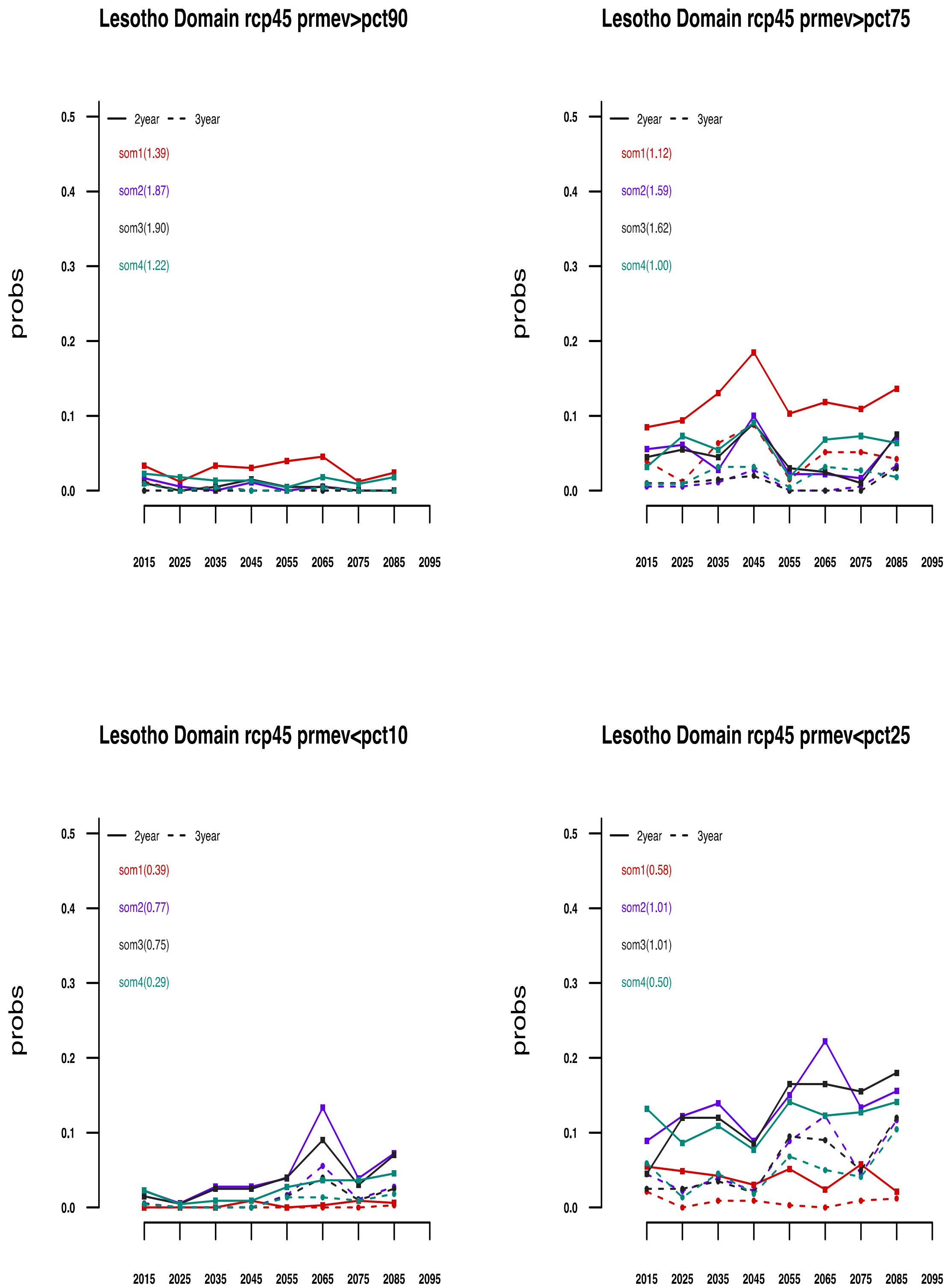


Figure LD10. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD9 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

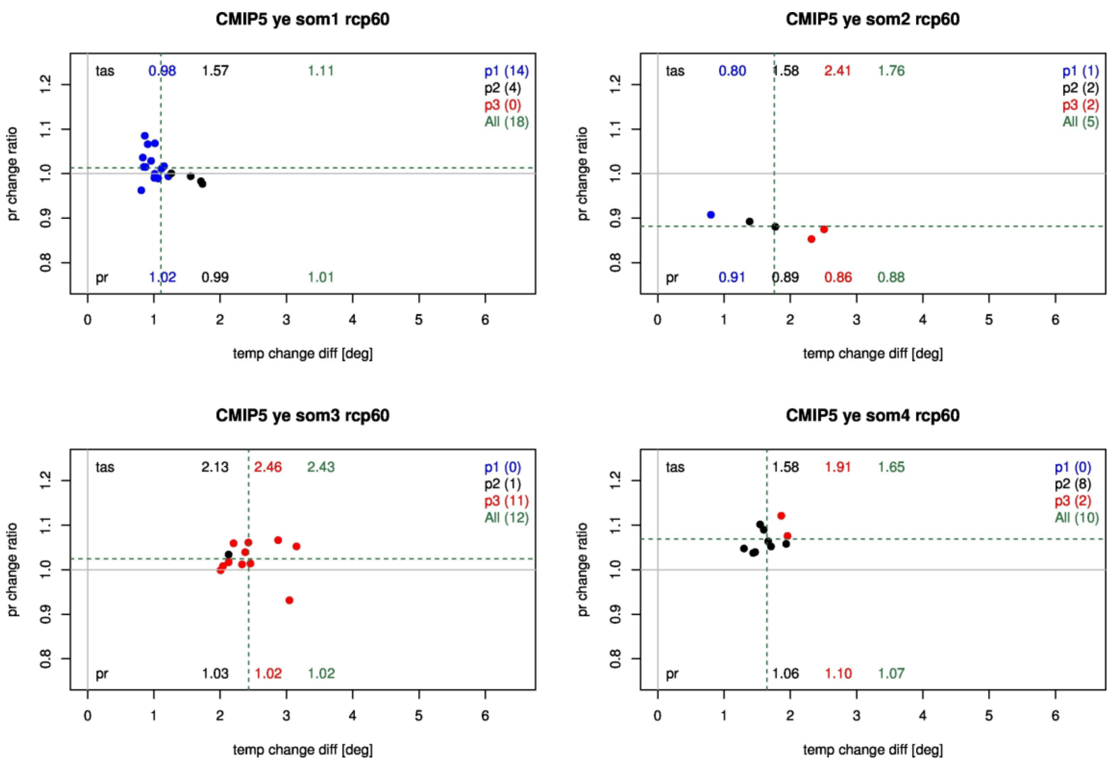


Figure LD11. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Lesotho Domain under RCP6.0 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 LD5a. Scenarios for the year over the Lesotho Domain under RCP6.0 based on Figure LD11 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
85	1→4→3	1.00ºC/1.00	1.50ºC/1.05	2.25ºC/1.05
15	1→2	1.00ºC/1.00	1.50ºC/0.95	2.50ºC/0.85

Summary: There is clear support for some increase in rainfall under RCP6.0. Most 2040 points are within som1, which gives the starting point for the two scenarios suggested.

RCP6.0; temperature vs rainfall

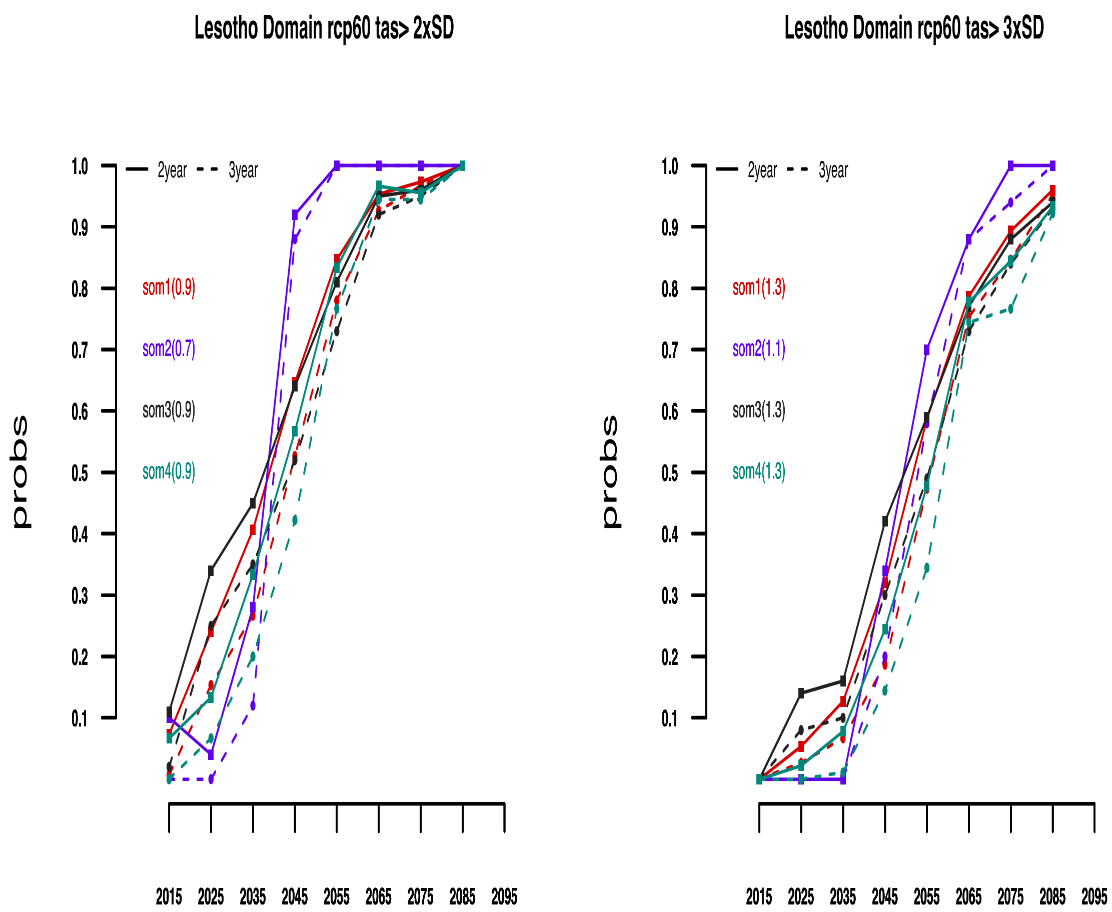


Figure LD12. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD11 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

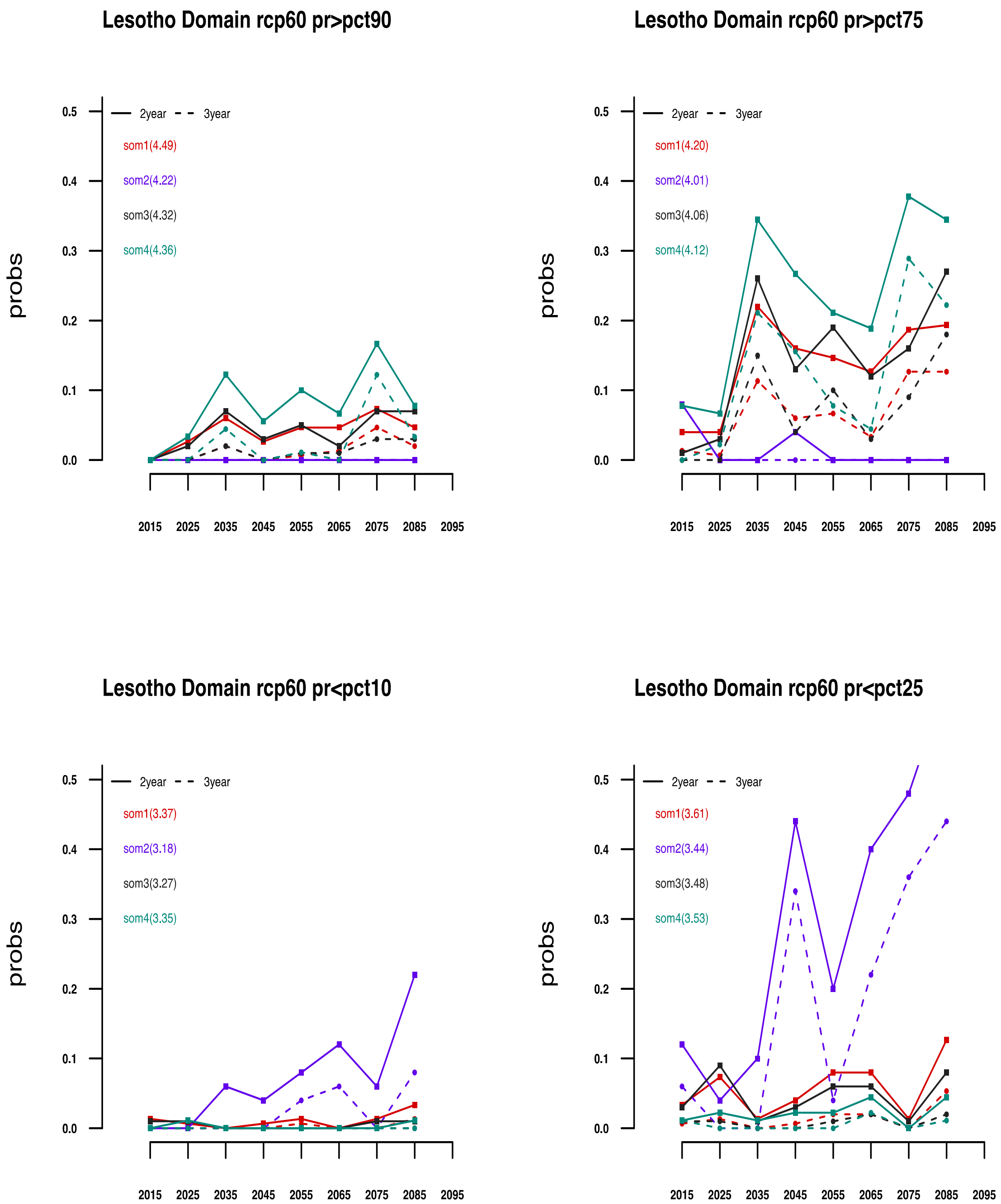


Figure LD13. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD11 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

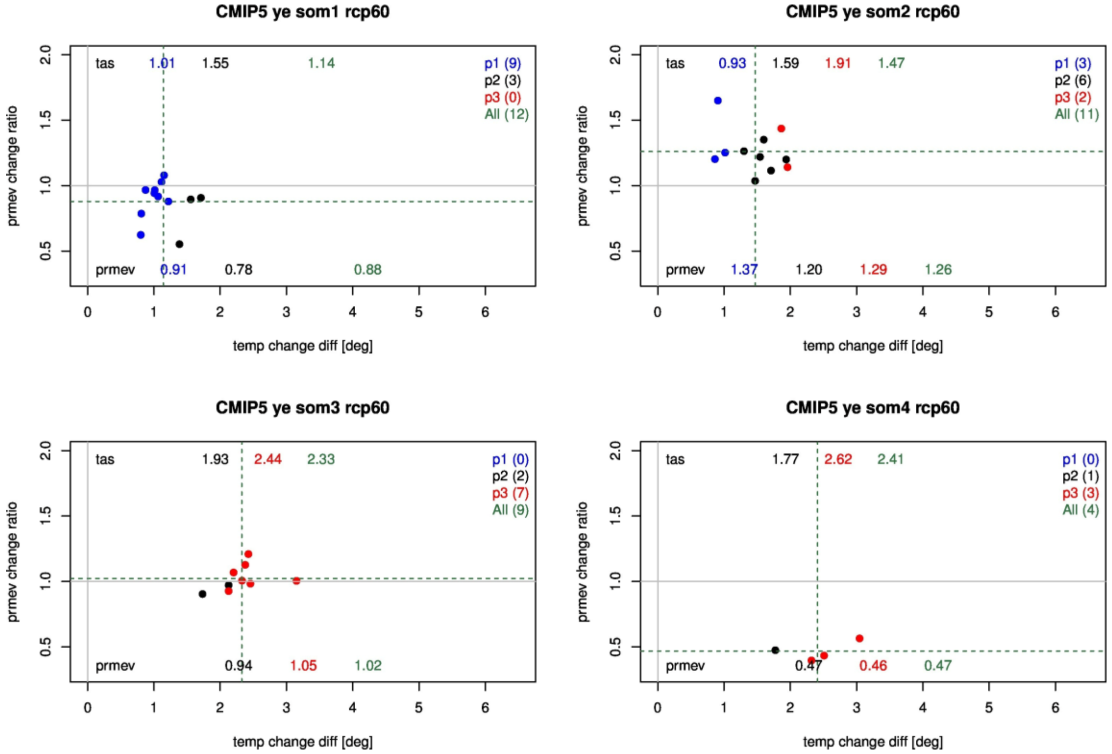


Figure LD14. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Lesotho Domain under RCP6.0; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 LD6a. Scenarios for the year over the Lesotho Domain under RCP6.0 based on Figure LD14 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
50	2→3	1.00ºC/1.35	1.50ºC/1.20	2.25ºC/1.05
50	1→4	1.00ºC/0.90	1.50ºC/0.80	2.50ºC/0.50

Summary: A further noisy analysis, certainly associated with the relatively small number of projections, but again likely with the complex terrain. Two roughly equal-likelihood scenarios emerge: one in which there is an increase in water availability, and a second, with higher temperatures possible later, with a reduction.

RCP6.0; temperature vs rainfall less evaporation

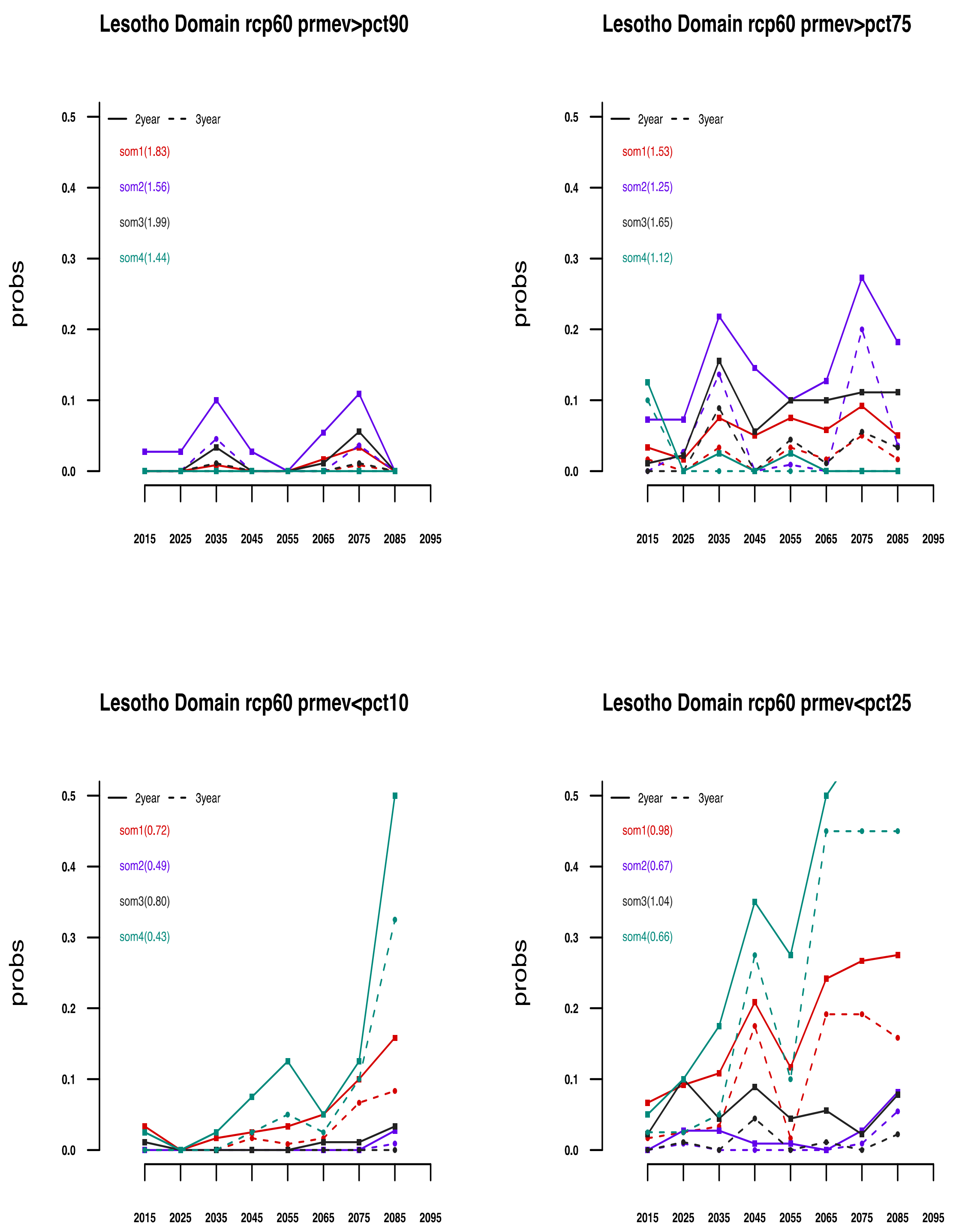


Figure LD117. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD14 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

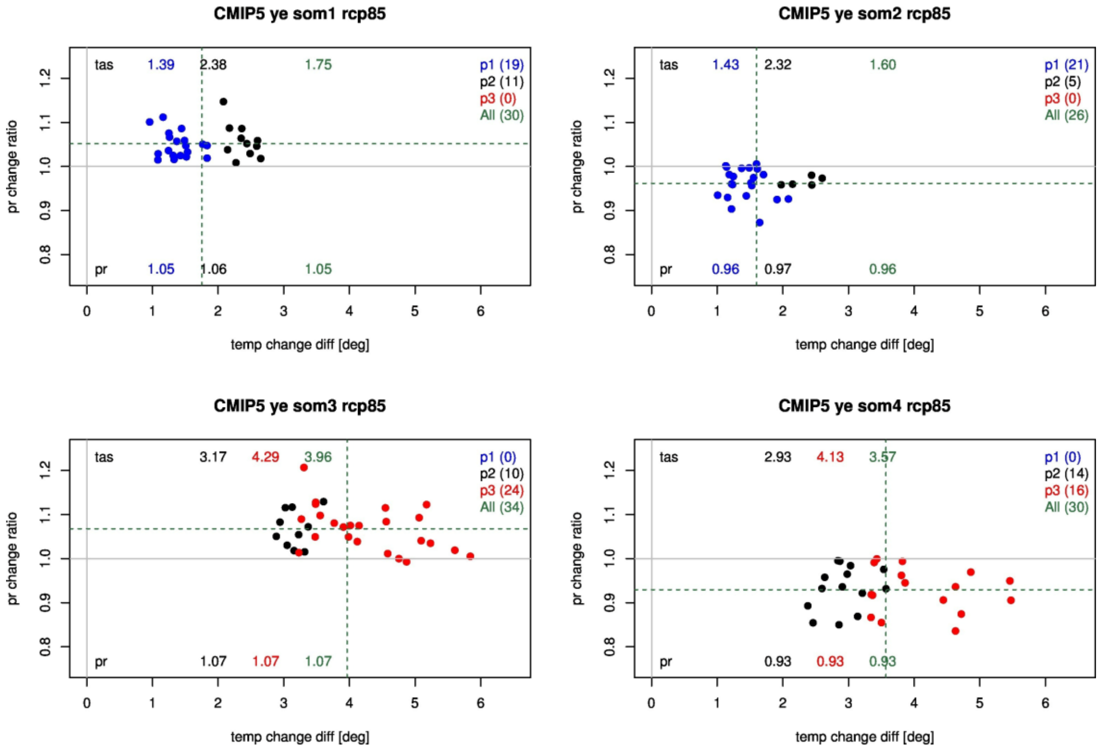


Figure LD16. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Lesotho Domain under RCP8.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 LD7a. Scenarios for the year over the Lesotho Domain under RCP8.5 based on Figure LD16 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	1.50ºC/1.05	2.75ºC/1.05	4.25ºC/1.05
50	2→4	1.50ºC/0.95	2.75ºC/0.95	4.25ºC/0.95

Summary: A simple split into two similar-likelihood scenarios differing only in either a 5% increase or a 5% decrease in rainfall.

RCP8.5; temperature vs rainfall

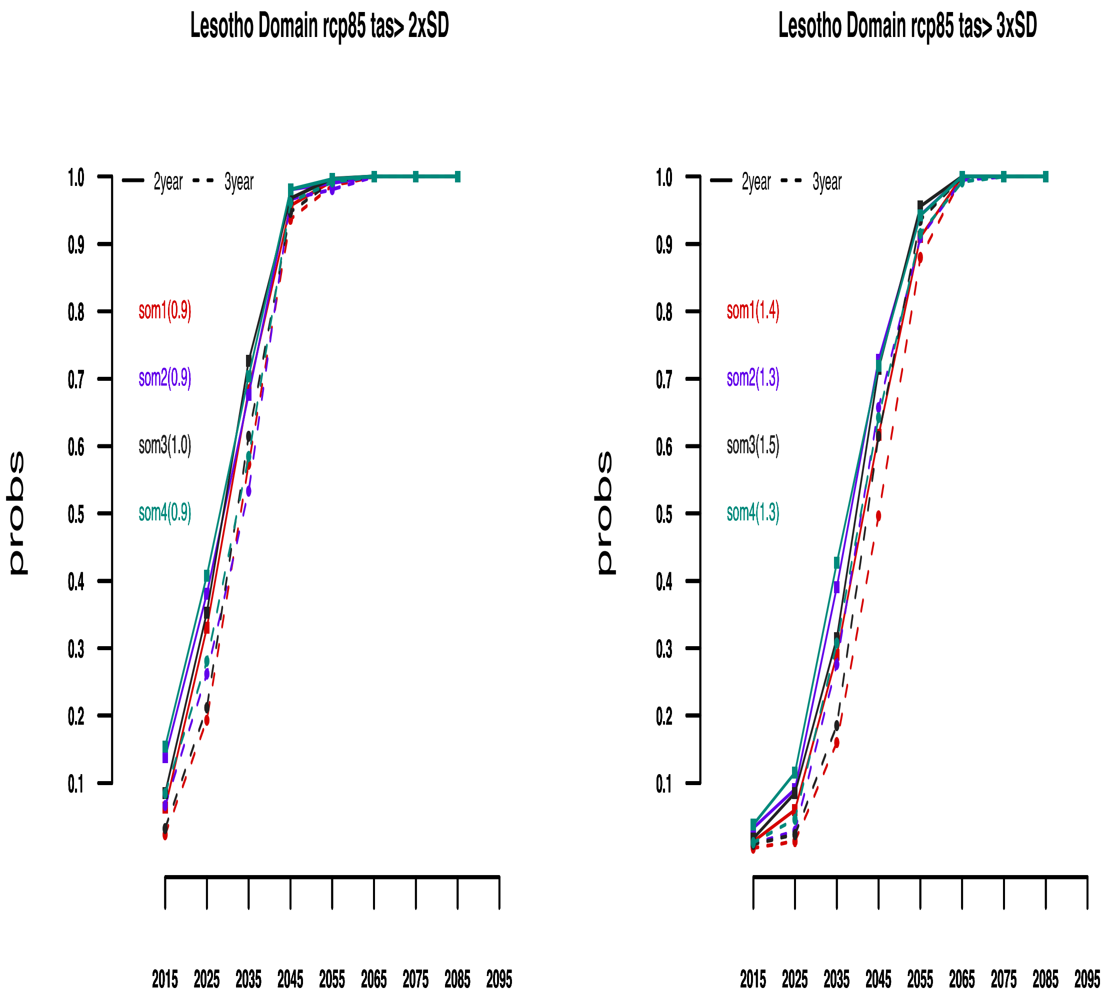


Figure LD17. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD16 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

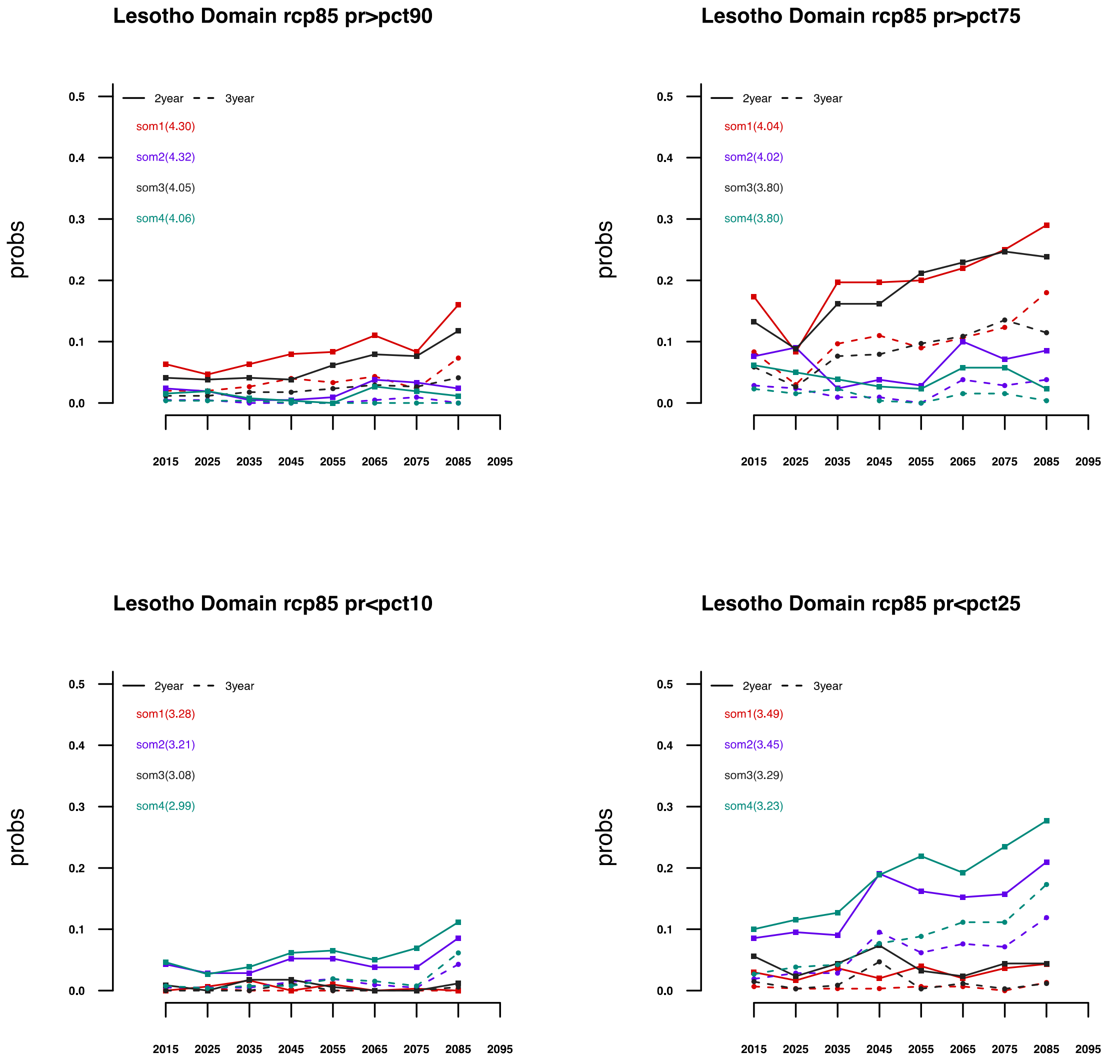


Figure LD18. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD16 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 less evaporation

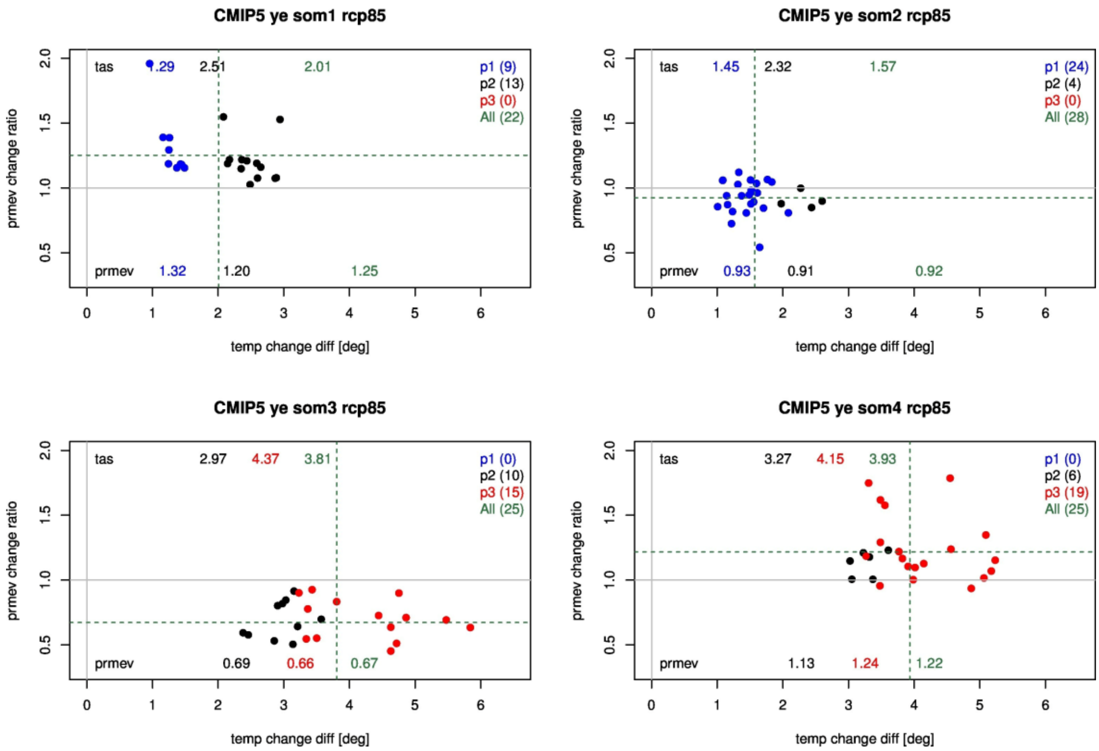


Figure LD19. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Lesotho Domain under RCP8.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 LD8a. Scenarios for the year over the Lesotho Domain under RCP8.5 based on Figure LD19 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	1→4	1.25ºC/1.30	2.75ºC/1.20	4.25ºC/1.25
45	2→3	1.50ºC/0.90	3.00ºC/0.75	4.50ºC/0.65

Summary: A split between wetter and drier with roughly equal likelihoods.

RCP8.5; temperature vs rainfall less evaporation

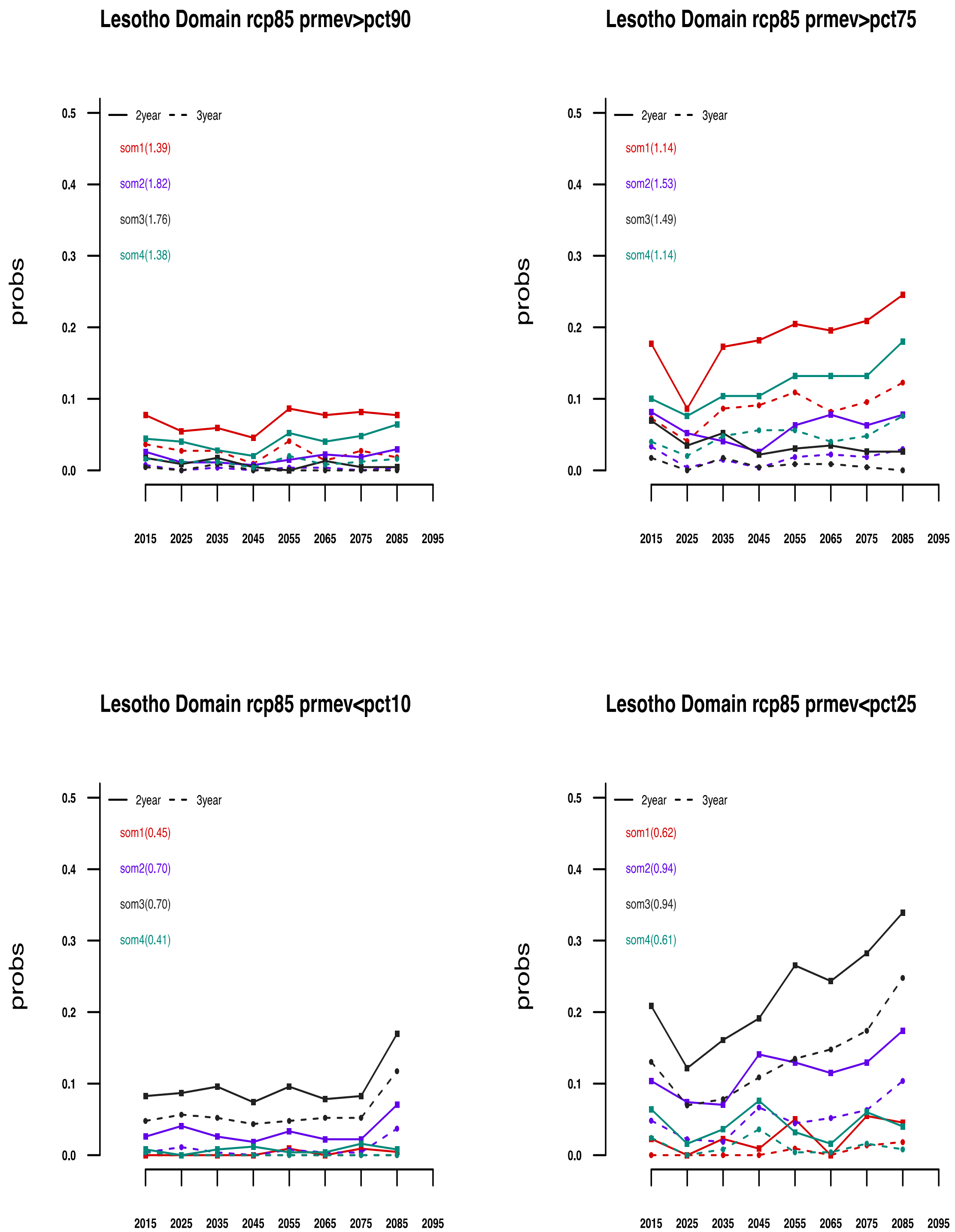


Figure LD20. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure LD19 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 Vaal Domain

Introduction. Results are presented below for the analyses through self-organising maps (soms) for the Vaal 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. A limited number of rainfall less evaporation projections have been eliminated subjectively from the analyses where over-large changes in rainfall less evaporation results because of near-zero rainfall less evaporation values during the base period of 1986-2005.

Also provided towards the end of this document are results for the inter-annual variability (IAV) calculations, in all cases located immediately after the soms charts to which they refer. 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 1986-2005. 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.

Summary of results. There is a distinct weighting towards future increases in rainfall from the temperature vs rainfall soms from RCP2.6, RCP4.5 and RCP6.0, but more of an equality in likelihoods for increases and decreases from the temperature vs rainfall less evaporation soms and from RCP8.5 in both sets of analyses.

Temperature against rainfall. As might be expected, temperatures in the RCP scenarios increase with emissions, a rise that is, in general, similar or greater for the drier scenarios. There is a distinct weight towards either continuance of current rainfall conditions or, more frequently, increased rainfall for all RCPs, an increase that is reflected in the recommended scenarios. As has been the case often in these soms analyses, RCP8.5 not only is responsible for higher temperatures but also for more equality between probabilities of rises and decreases in rainfall.

Temperatures in the suggested 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 1986-2005 increase, naturally, with RCP, but vary also according to individual soms. Under RCP8.5 successive two- and three-year periods are almost certain by the 2050's for two standard deviations and by the 2060's for three standard deviations. By contrast, under RCP2.6 only one of the soms produces 100%

probabilities (by the 2040'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 80%. For RCP4.5 and RCP6.0 100% probabilities are reached by a single som for two standard deviations by the 2080's, although for the other soms the probabilities are around 90.

Likelihoods of annual rainfall totals outside the 10th and 90th percentiles over 2 and 3 years do not change substantially with RCP, in general being below 10%. Nor does there seem to be much change in likelihoods for both in time. For many soms likelihoods remain below 10% throughout but for certain ones these may rise towards 30% or higher; this is particularly the case for below the 25th percentile for all RCPs and for above the 75th percentile for the higher two RCPs. Note that there is likely to be extra noise in results for RCP2.6 and RCP6.0.

Temperature against rainfall less evaporation. There are similar likelihoods of increased and of decreased rainfall less evaporation, even for RCP8.5, unlike the case for the rainfall only assessment. There might be a slight bias towards warmer temperatures with reduced water availability; warmest temperatures, naturally, occur with RCP8.5.

Temperatures in the recommended extreme scenarios increase in general with RCP. According to these scenarios changes in rainfall less evaporation might reach ±30%, even ±50% according to 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 increased above there towards the end of the century for the higher RCPs. For RCP6.0 and RCP8.5 there are suggestions of possible increased frequencies of events below the 10th percentile. However, there are increasing likelihoods of 2/3 year values outside the 25th and 75th percentiles as the century proceeds for most RCPs. 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 20% or more.

Conclusions. In section 3 of the main report it was noted that the Vaal Domain sits at a location approximately where projected rainfall tends to increase for most ensemble means with all RCPs whereas there is more of a split between increases and decreases for projected rainfall less evaporation. These soms results appear consistent with that, with a bias towards increased rainfall in the former case but more equality in likelihoods in the latter. Presumably the distinction is related to the response of evaporation to increased temperatures. 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. It suggests a notably increased likelihood of increased rainfall in the temperature vs rainfall analyses but approximately similar prospects of increased and decreased water availability in the temperature vs rainfall less evaporation analyses. These differences in likelihoods 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 in 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, although chances perhaps increase a little under RCP6.0 and RCP8.5, but those for the 25th and 90th percentiles do (although not for all soms) for most RCPs, suggesting an increase in spread of annual values and with possible slight bias towards drier conditions.

RCP8.5; temperature vs rainfall less evaporation

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

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
75	1.00ºC/1.00	1.50ºC/1.05	2.00ºC/1.05
25	1.00ºC/0.95	1.50ºC/0.90	2.00ºC/0.90

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	2.50ºC/1.10
Decreased	1.00ºC/0.90	1.75ºC/0.85	2.25ºC/0.85

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
50	1.05ºC/1.05	1.50ºC/1.10	2.00ºC/1.10
50	1.05ºC/0.90	1.75ºC/0.90	2.00ºC/0.85

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	1.50ºC/1.30	2.00ºC/1.30
Decreased	1.00ºC/0.70	1.75ºC/0.70	2.25ºC/0.70

RCP8.5; temperature vs rainfall less evaporation

Recommended Scenarios for the Vaal Domain based on RCP8.5

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
45	1.50ºC/1.00	2.75ºC/0.95	4.00ºC/0.90
40	1.50ºC/1.00	2.75ºC/1.05	3.75ºC/1.05
15	1.50ºC/1.00	2.25ºC/1.00	5.00ºC/1.00

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

	2040	2065	2080
Increased	1.50ºC/1.10	2.75ºC/1.15	3.50ºC/1.20
Decreased	1.50ºC/0.85	2.75ºC/0.85	4.50ºC/0.80

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
50	1.50ºC/1.00	2.75ºC/1.20	4.00ºC/1.30
35	1.50ºC/1.00	3.00ºC/0.80	3.50ºC/0.75
15	1.50ºC/1.00	2.50ºC/1.00	5.00ºC/0.80

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

	2040	2065	2080
Increased	1.25ºC/1.30	2.50ºC/1.50	5.00ºC/1.50
Decreased	1.50ºC/0.60	3.00ºC/0.60	4.50ºC/0.50

RCP8.5; temperature vs rainfall less evaporation

Scenarios from each RCP for the Vaal 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 17 projections

	%		2040	2065	2080		%		2040	2065	2080
1	35	2	1.25ºC/1.00	1.25ºC/1.05	1.25ºC/1.00		60	1→4	1.25ºC/0.95	1.25ºC/0.90	1.25ºC/0.85
2	30	4	0.75ºC/1.05	0.75ºC/1.05	0.75ºC/1.05		30	3	0.75ºC/1.10	0.75ºC/1.05	0.75ºC/1.10
3	20	1	1.00ºC/0.90	1.00ºC/0.95	1.25ºC/0.95		10	2	2.00ºC/0.90	2.00ºC/1.20	2.00ºC/0.95
4	15	3	2.00ºC/0.95	2.00ºC/1.00	2.00ºC/1.00						

Summary: In TRLE there is a clear weighting towards decreased water availability (Line 1 with estimated likelihood of 60%) – the decrease in Line 3 (10%) might be neglected as it is based on a single som with low population. The two recommended scenarios in TR with greatest tendencies to decreased water availability are in Lines 3 and 4 with combined likelihood of 35%. Hence there two separate analyses do not accord fully in terms of likelihoods of reduced water availability.

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/1.10	1.00ºC/1.10	1.00ºC/1.10		1.75ºC/1.40	2.00ºC/1.30	2.00ºC/1.10
Decreased	1.00ºC/0.85	1.25ºC/0.85	1.25ºC/0.90		1.00ºC/0.60	1.25ºC/0.60	1.75ºC/0.80

RCP4.5 – 38 and 30 projections

	%		2040	2065	2080		%		2040	2065	2080
1	45	2→1	1.25ºC/1.00	1.75ºC/1.00	1.75ºC/1.00		55	2→4	1.25ºC/0.80	2.00ºC/0.85	2.25ºC/0.80
2	40	2→4	1.25ºC/1.00	1.75ºC/1.05	2.50ºC/1.05		45	1→3	1.00ºC/1.05	1.50ºC/1.15	2.50ºC/1.15
3	15	2→3	1.25ºC/0.95	1.50ºC/0.90	1.75ºC/0.90						

Summary: As for RCP2.6 in TRLE there is weighting, albeit relatively small, towards decreased water availability (Line 1, 55%) whereas in TR decreases have lesser likelihood (Line 3, 15%).

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

RCP8.5; temperature vs rainfall less evaporation

	2040	2065	2080		2040	2065	2080
Increased	1.25°C/1.10	1.75°C/1.10	2.50°C/1.10		1.00°C/1.30	1.25°C/1.30	2.50°C/1.30
Decreased	1.00°C/0.90	2.00°C/0.85	2.50°C/0.85		1.00°C/0.70	2.50°C/0.70	3.00°C/0.60

RCP6.0 – 15 and 10 projections

	%		2040	2065	2080		%		2040	2065	2080
1	50	1→4	1.00°C/1.00	1.50°C/1.00	2.50°C/1.00		70	1→3	1.00°C/1.00	1.50°C/1.05	2.25°C/1.20
2	40	1→3	1.00°C/1.00	1.50°C/1.05	2.25°C/1.10		30	2→4	1.00°C/0.75	1.75°C/0.75	2.75°C/0.90
3	10	1→2	1.00°C/1.00	1.50°C/0.95	2.25°C/0.85						

Summary: Contrary to RCP2.6 and RCP4.5, in TRLE for RCP6.0 the highest likelihood is for an increase in water availability (Line 1, 70%); perhaps in TR there is also a tendency towards no decrease (Line 1, 50%, plus Line 2, 40%).

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	1.00°C/1.10	1.75°C/1.10	3.00°C/1.10		1.00°C/1.30	1.50°C/1.20	2.00°C/1.20
Decreased	0.75°C/0.90	1.75°C/0.90	2.25°C/0.85		0.75°C/0.70	1.75°C/0.60	3.00°C/0.60

RCP8.5 – 40 and 34 projections

	%		2040	2065	2080		%		2040	2065	2080
1	45	1→2	1.50°C/1.00	2.75°C/0.95	4.00°C/0.90		50	1→3	1.50°C/1.00	2.75°C/1.20	4.00°C/1.30
2	40	1→3	1.50°C/1.00	2.75°C/1.05	3.75°C/1.05		35	1→2	1.50°C/1.00	3.00°C/0.80	3.50°C/0.75
3	15	1→4	1.50°C/1.00	2.25°C/1.00	5.00°C/1.00		15	1→4	1.50°C/1.00	2.50°C/1.00	5.00°C/0.80

Summary: There is perhaps a roughly equal split in both cases between increased and decreased water availability, in TR Line 2 (40%) as against Line 1 (45%) and in TRLE Line 1 (50%) and Lines 2 plus 3 (50%) respectively.

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	1.50°C/1.10	2.75°C/1.15	3.50°C/1.20		1.25°C/1.30	2.50°C/1.50	5.00°C/1.50
Decreased	1.50°C/0.85	2.75°C/0.85	4.50°C/0.80		1.50°C/0.60	3.00°C/0.60	4.50°C/0.50

RCP2.6; temperature vs rainfall

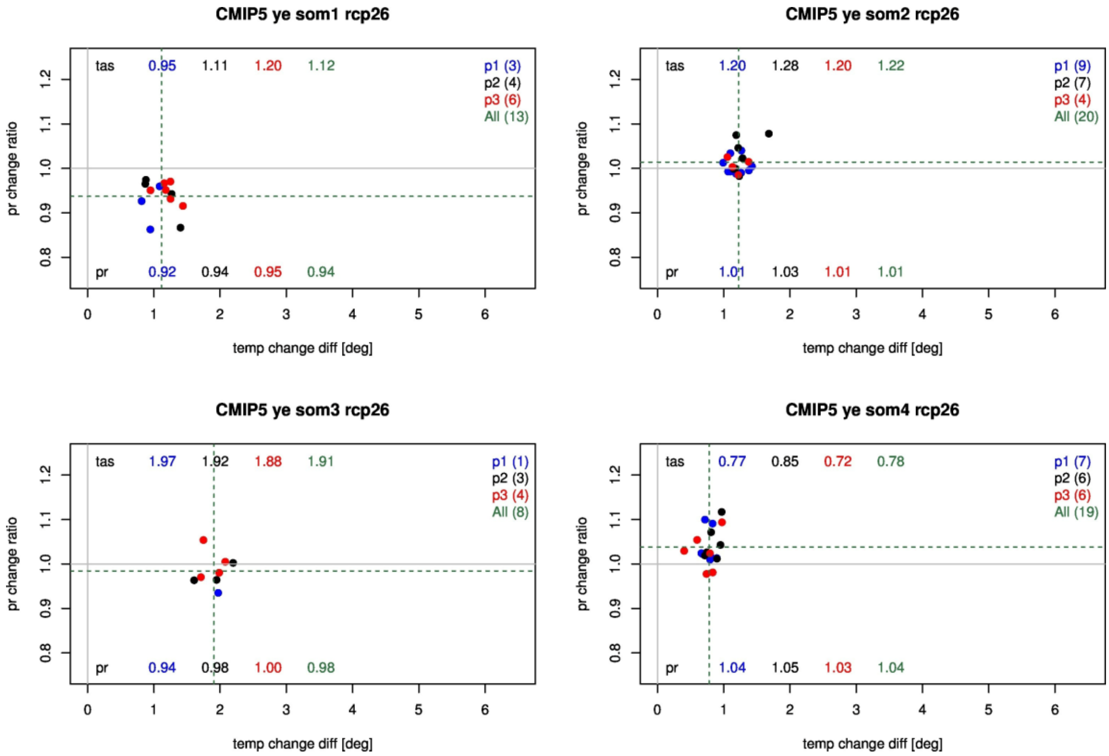


Figure VD18. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Vaal Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 VD1a. Scenarios for the year over the Vaal Domain under RCP2.6 based on Figure VD1 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	2	1.25ºC/1.00	1.25ºC/1.05	1.25ºC/1.00
30	4	0.75ºC/1.05	0.75ºC/1.05	0.75ºC/1.05
20	1	1.00ºC/0.90	1.00ºC/0.95	1.25ºC/0.95
15	3	2.00ºC/0.95	2.00ºC/1.00	2.00ºC/1.00

Summary: All 4 soms appear self-contained and independent. Hence four preliminary scenarios.

RCP2.6; temperature vs rainfall

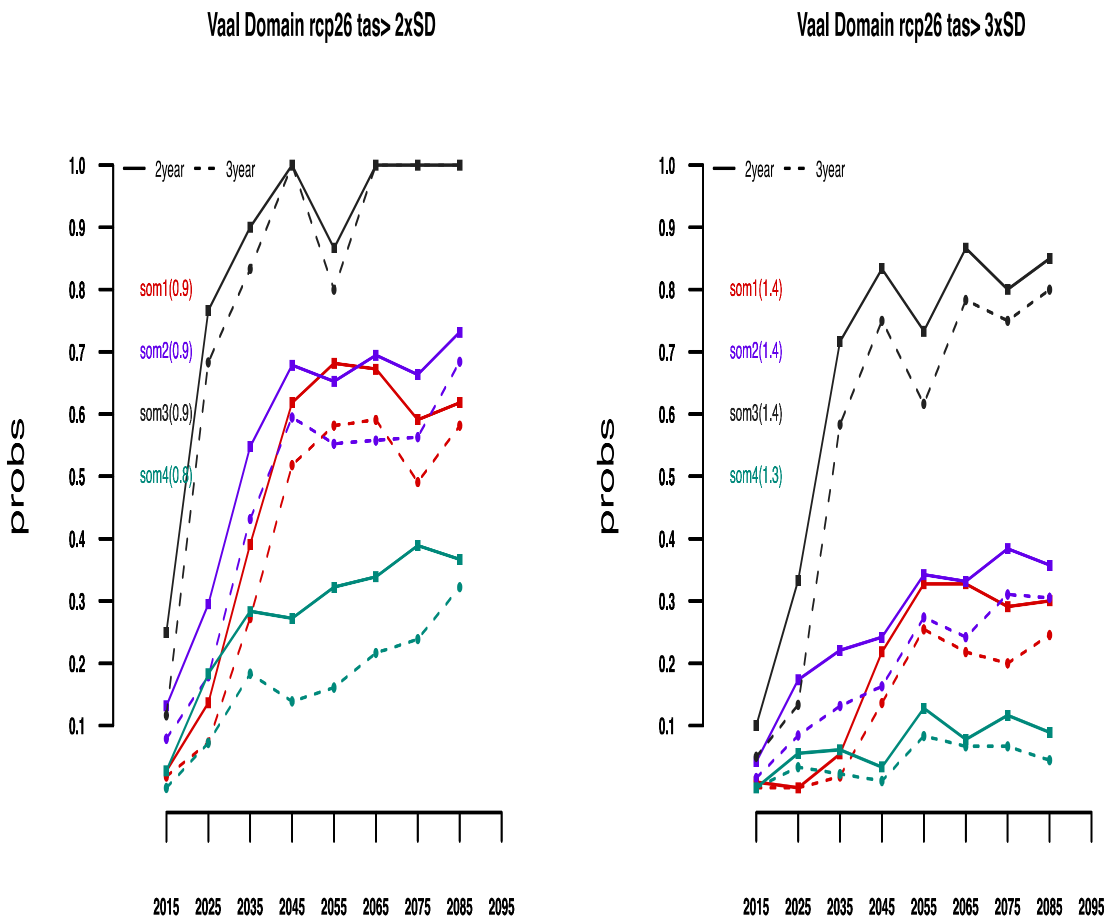


Figure VD19. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD1 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

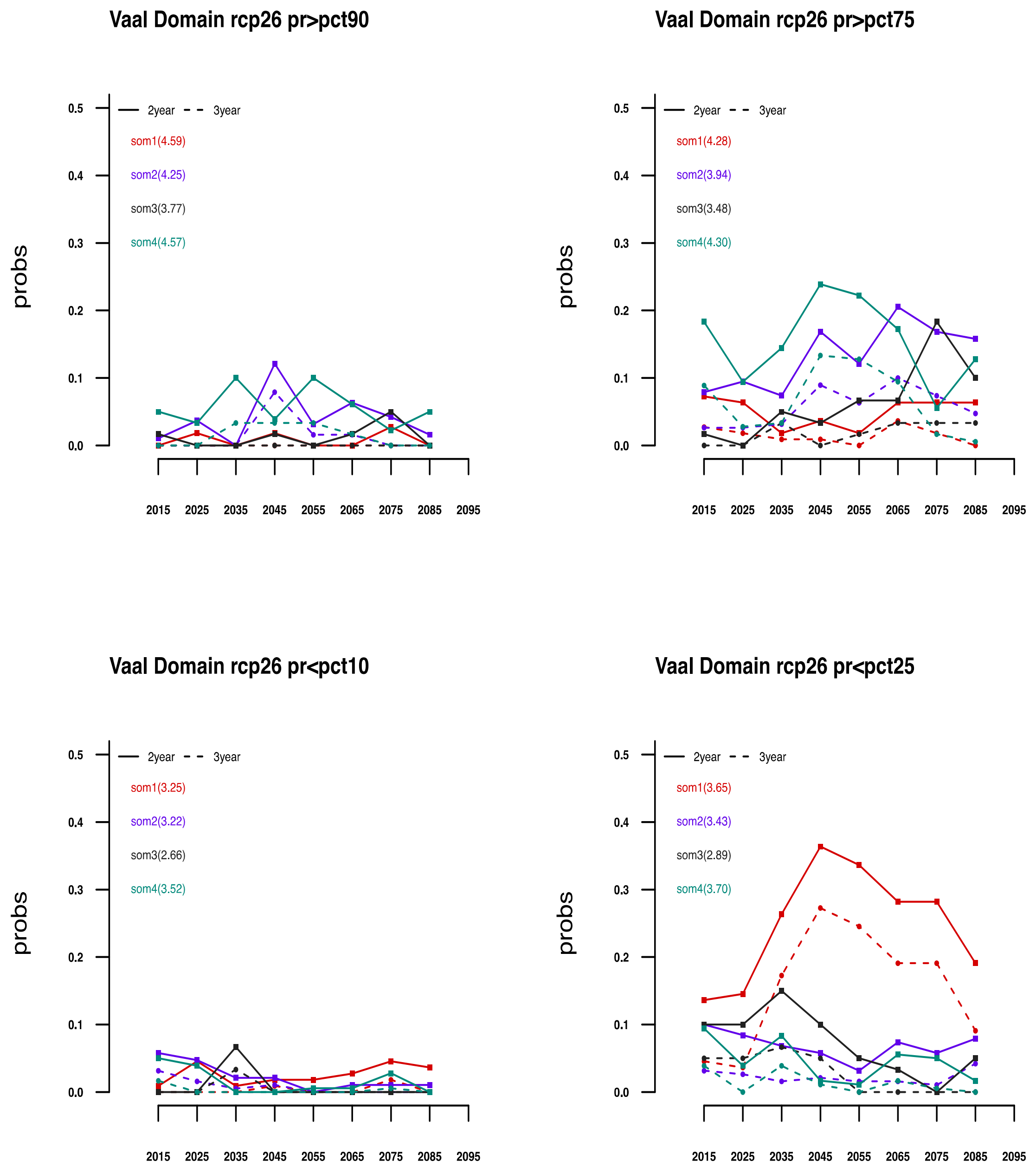


Figure VD20. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD1 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

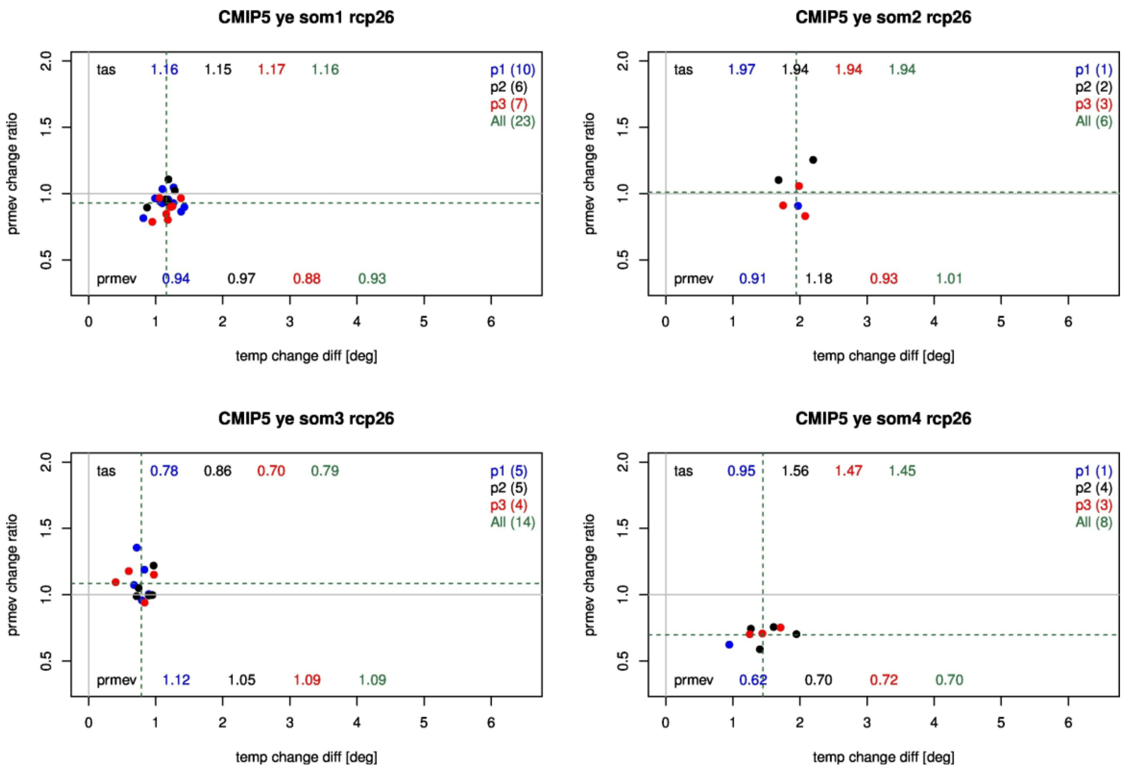


Figure VD4. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Vaal Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 17 projections in CMIP5 for RCP2.6.

Table VD2a. Scenarios for the year over the Vaal Domain under RCP2.6 based on Figure VD4 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→4	1.25ºC/0.95	1.25ºC/0.90	1.25ºC/0.85
30	3	0.75ºC/1.10	0.75ºC/1.05	0.75ºC/1.10
10	2	2.00ºC/0.90	2.00ºC/1.20	2.00ºC/0.95

Summary: Although there are three suggested scenarios the least likely one appears to join a few projections inconsistent with the remainder, and erratic as far as rainfall less evaporation is concerned. Hence a more likely warmer/drier scenario plus a cooler/wetter scenario.

RCP2.6; temperature vs rainfall less evaporation

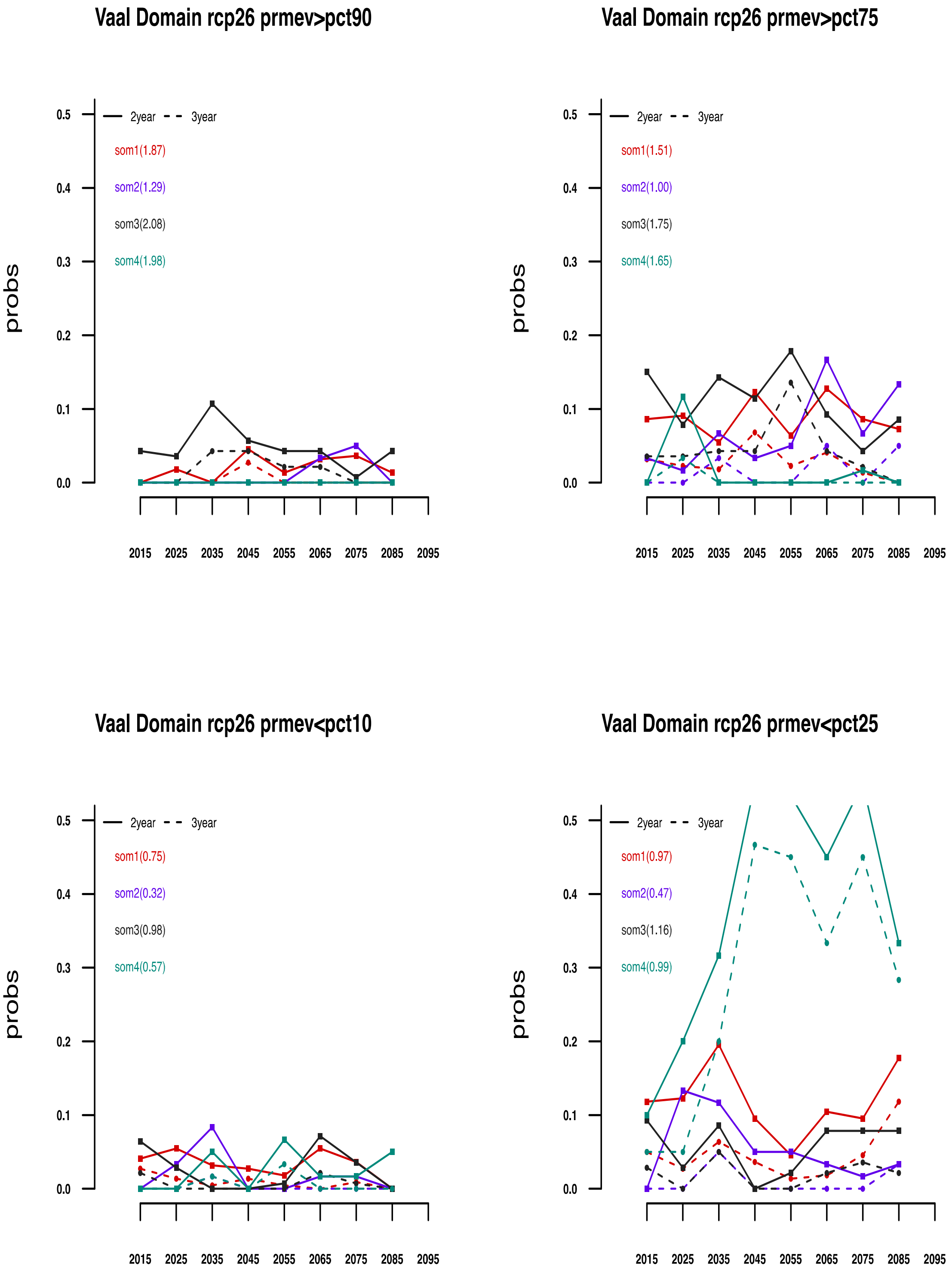


Figure VD5. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD4 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

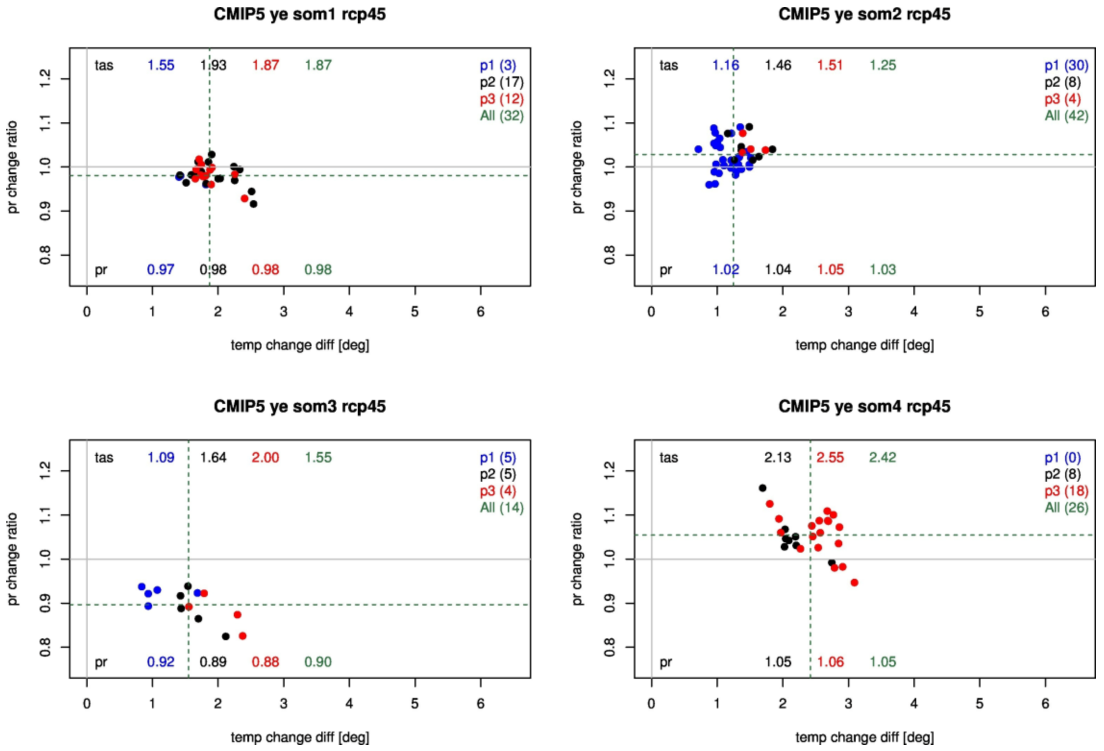


Figure VD6. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Vaal Domain under RCP4.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 VD3a. Scenarios for the year over the Vaal Domain under RCP4.5 based on Figure VD6 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→1	1.25ºC/1.00	1.75ºC/1.00	1.75ºC/1.00
40	2→4	1.25ºC/1.00	1.75ºC/1.05	2.50ºC/1.05
15	2→3	1.25ºC/0.95	1.50ºC/0.90	1.75ºC/0.90

Summary: All three scenarios start in som2 as that is where the majority of 2040 points lie.

RCP4.5; temperature vs rainfall

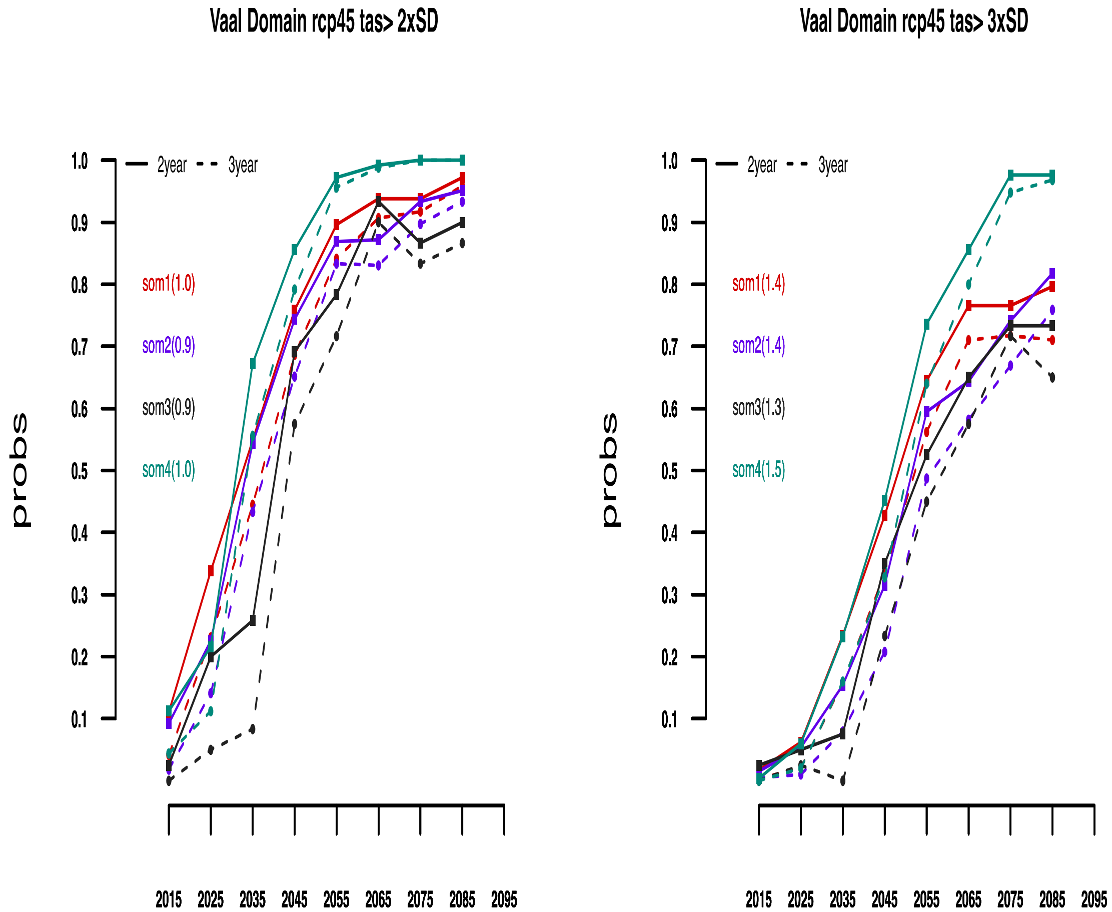


Figure VD7. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD6 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

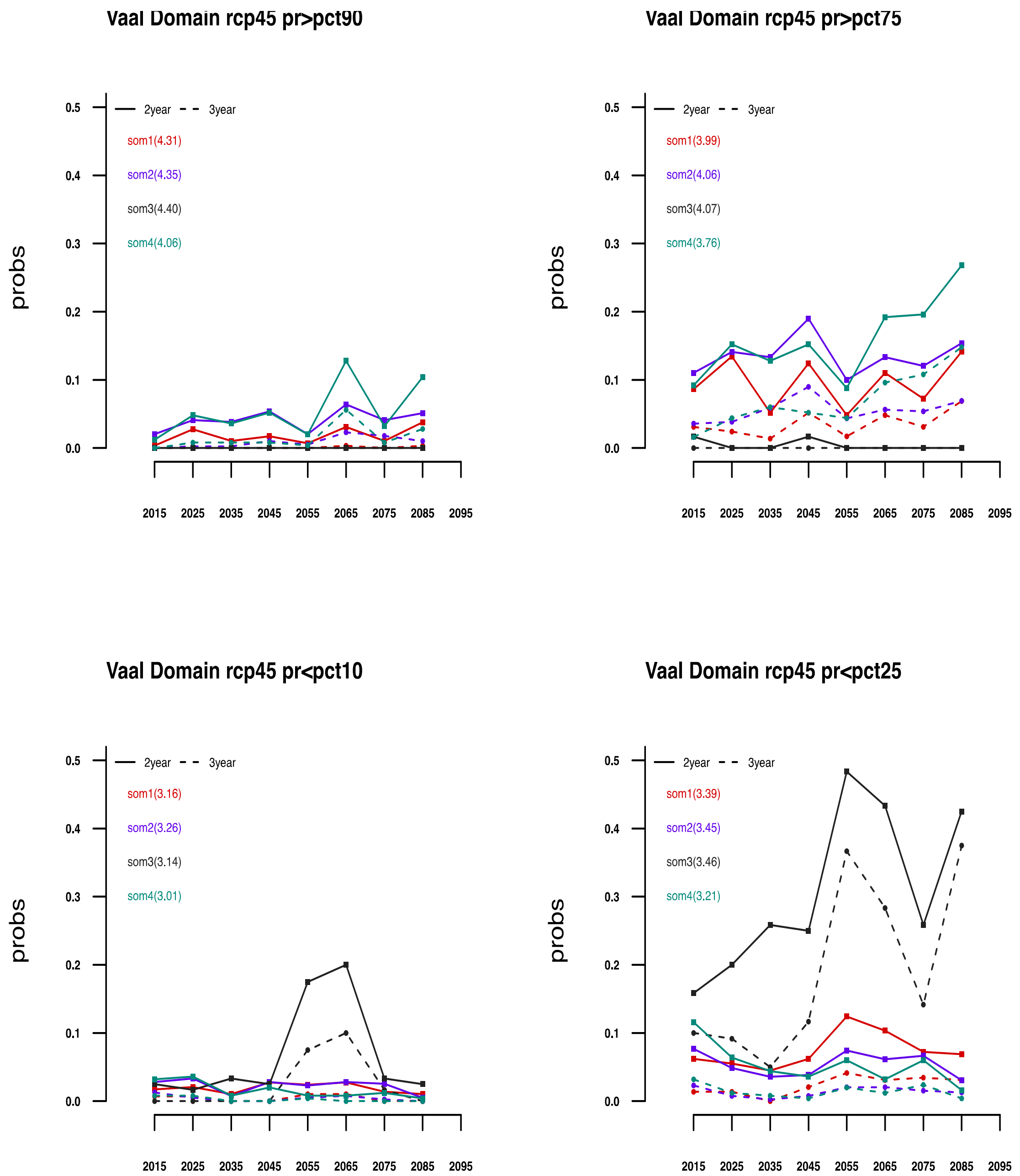


Figure VD8. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD6 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

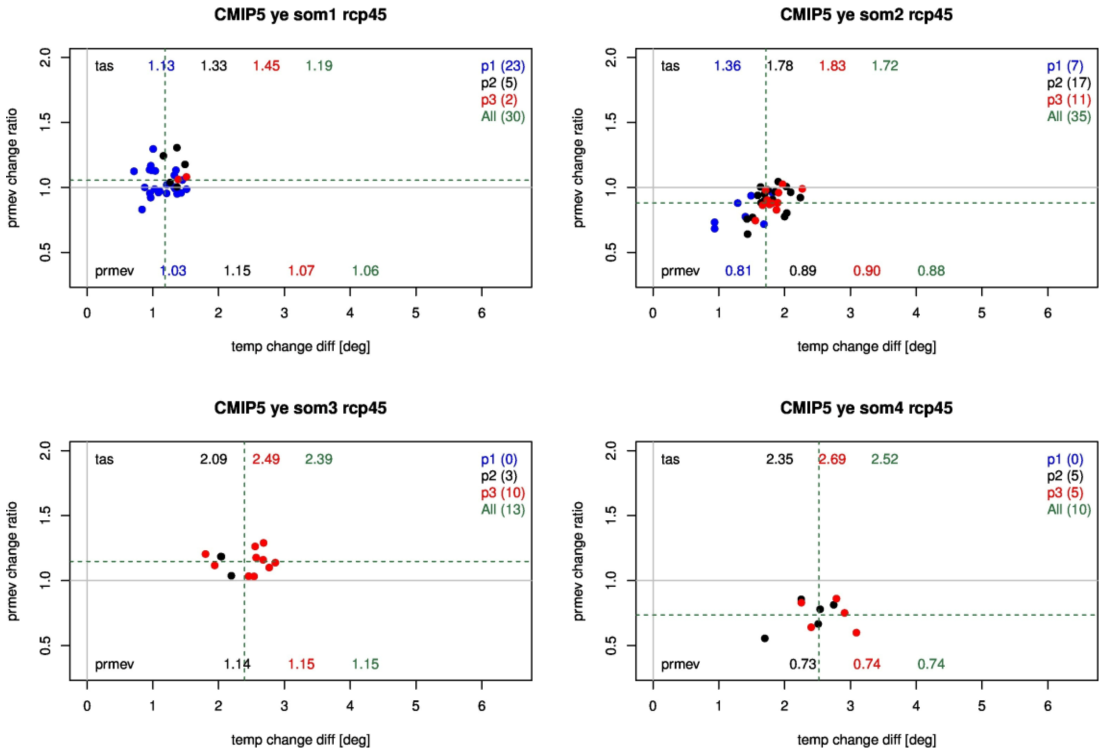


Figure VD9. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Vaal Domain under RCP4.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 30 projections in CMIP5 for RCP4.5.

Table VD4a. Scenarios for the year over the Vaal Domain under RCP4.5 based on Figure VD9 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	2→4	1.25ºC/0.80	2.00ºC/0.85	2.25ºC/0.80
45	1→3	1.00ºC/1.05	1.50ºC/1.15	2.50ºC/1.15

Summary: Two scenarios have been suggested, although alternate interpretations may be possible.

RCP4.5; temperature vs rainfall less evaporation

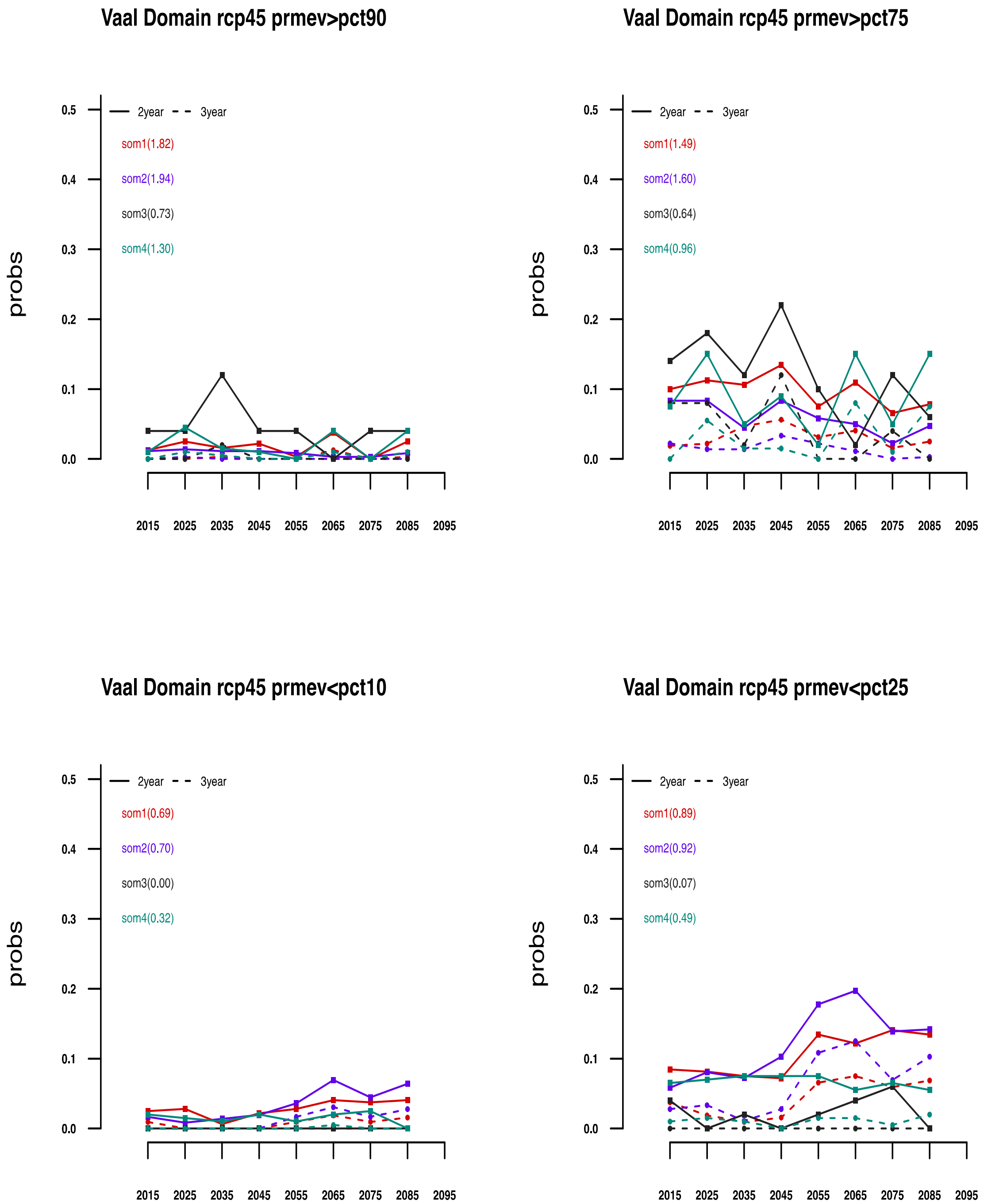


Figure VD10. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD9 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

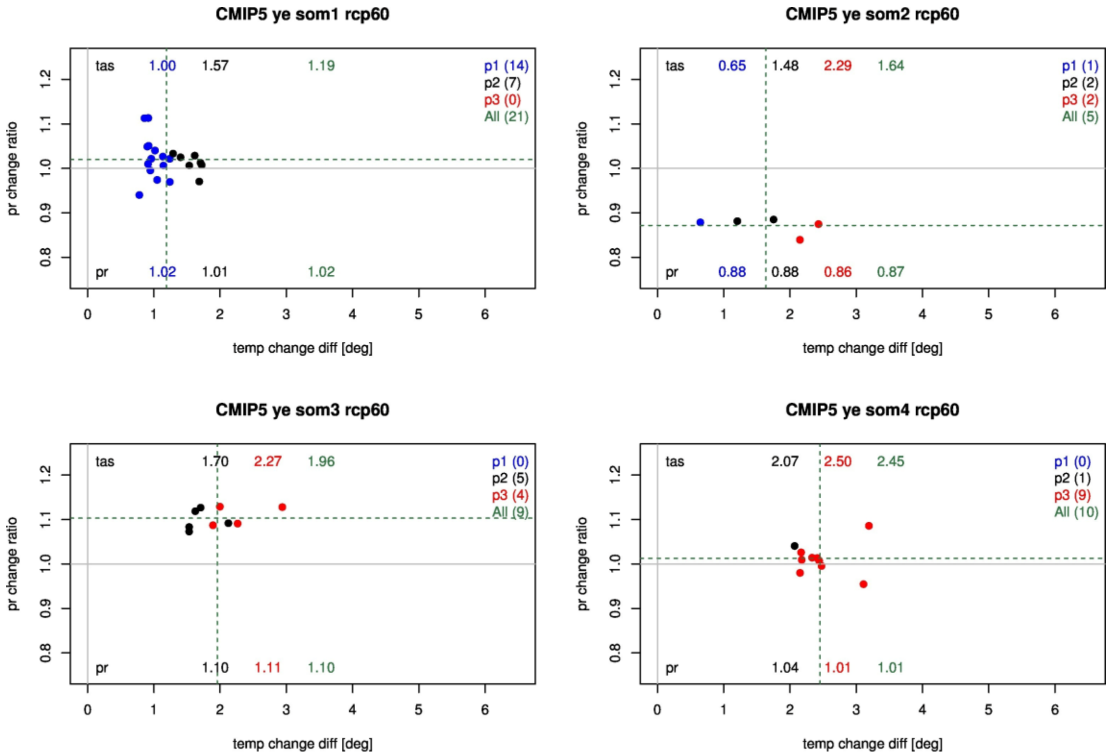


Figure VD11. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Vaal Domain under RCP6.0 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 VD5a. Scenarios for the year over the Vaal Domain under RCP6.0 based on Figure VD11 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→4	1.00ºC/1.00	1.50ºC/1.00	2.50ºC/1.00
40	1→3	1.00ºC/1.00	1.50ºC/1.05	2.25ºC/1.10
10	1→2	1.00ºC/1.00	1.50ºC/0.95	2.25ºC/0.85

Summary: With almost all 2040 projections within som1 the three suggested scenarios all start from this point. The majority vote here is for little change or for an increase in rainfall.

RCP6.0; temperature vs rainfall

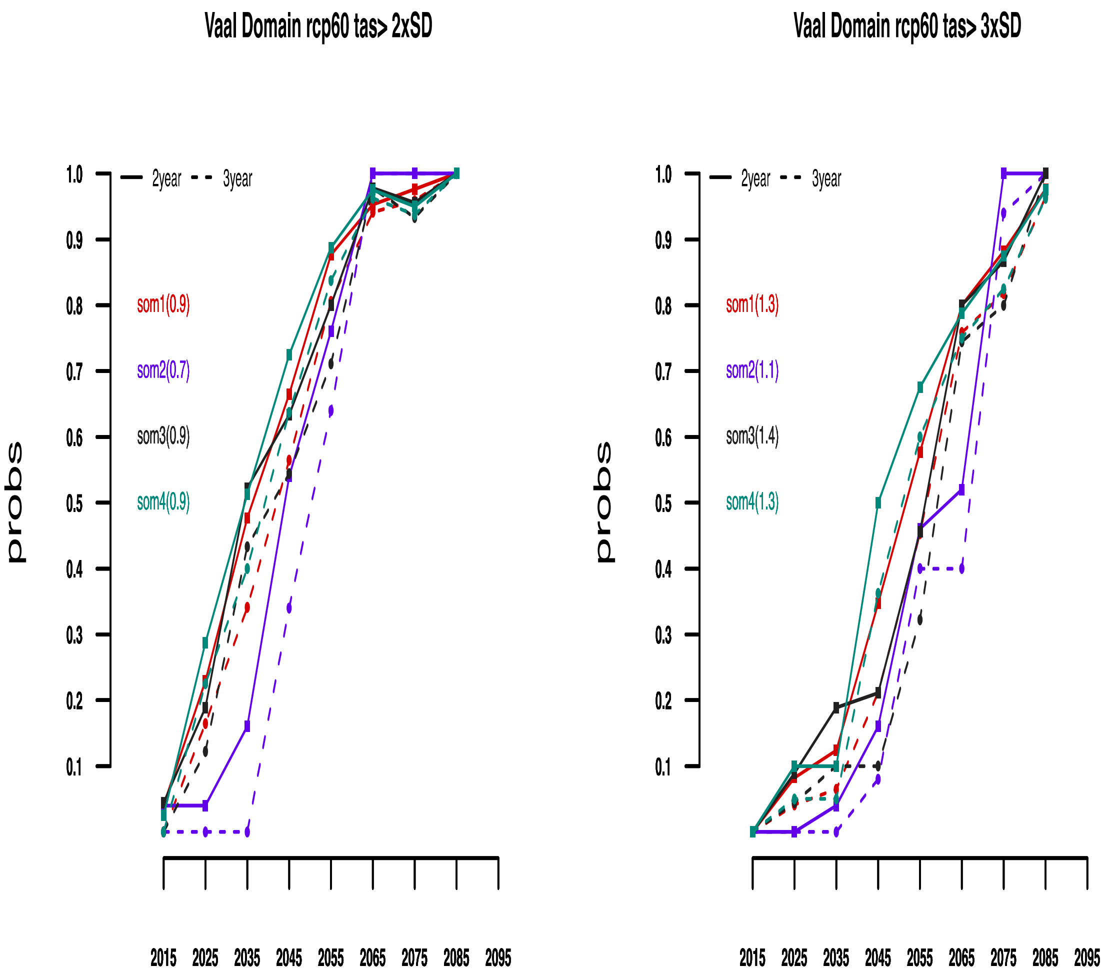


Figure VD12. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD11 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

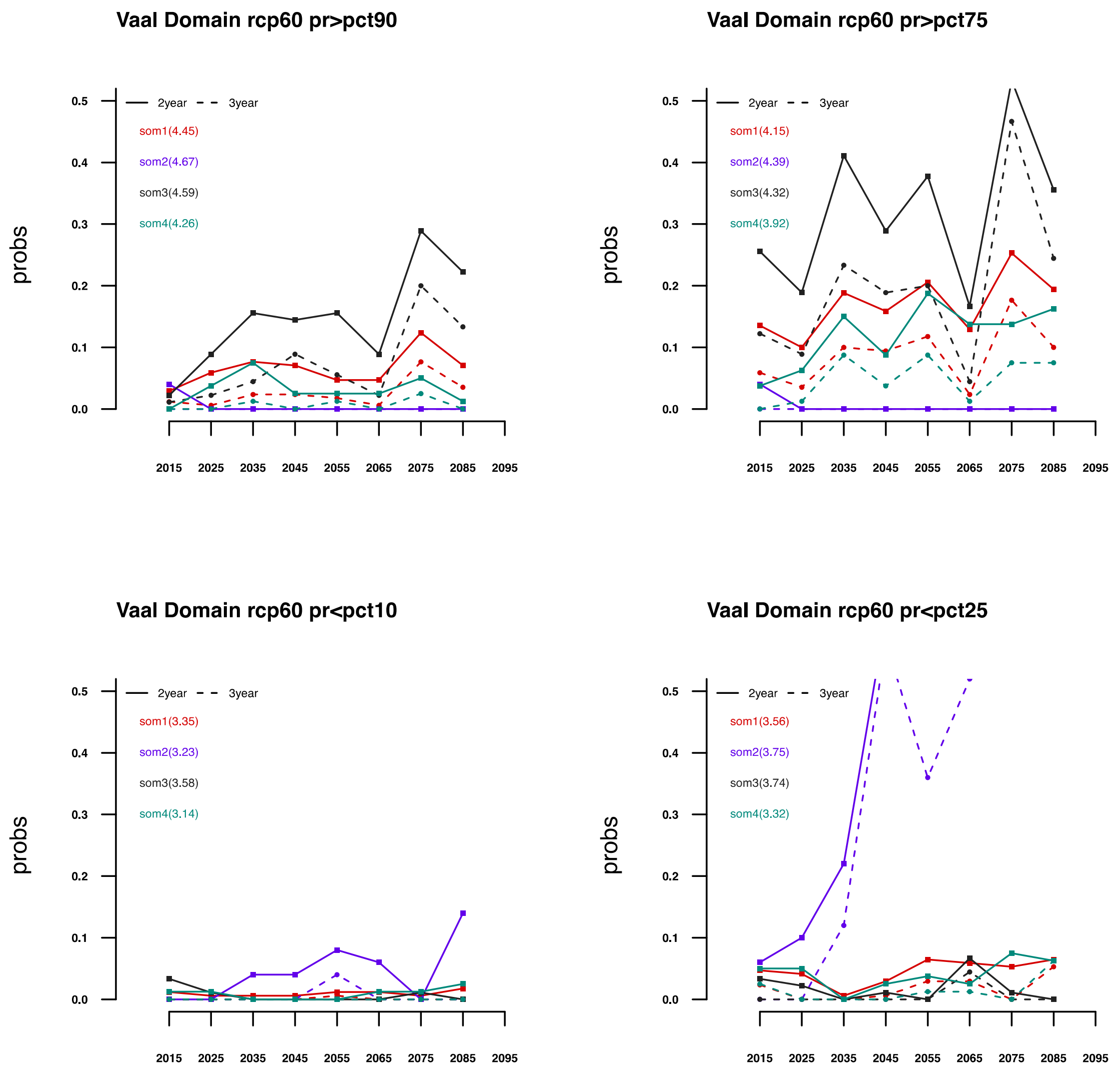


Figure VD13. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD11 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

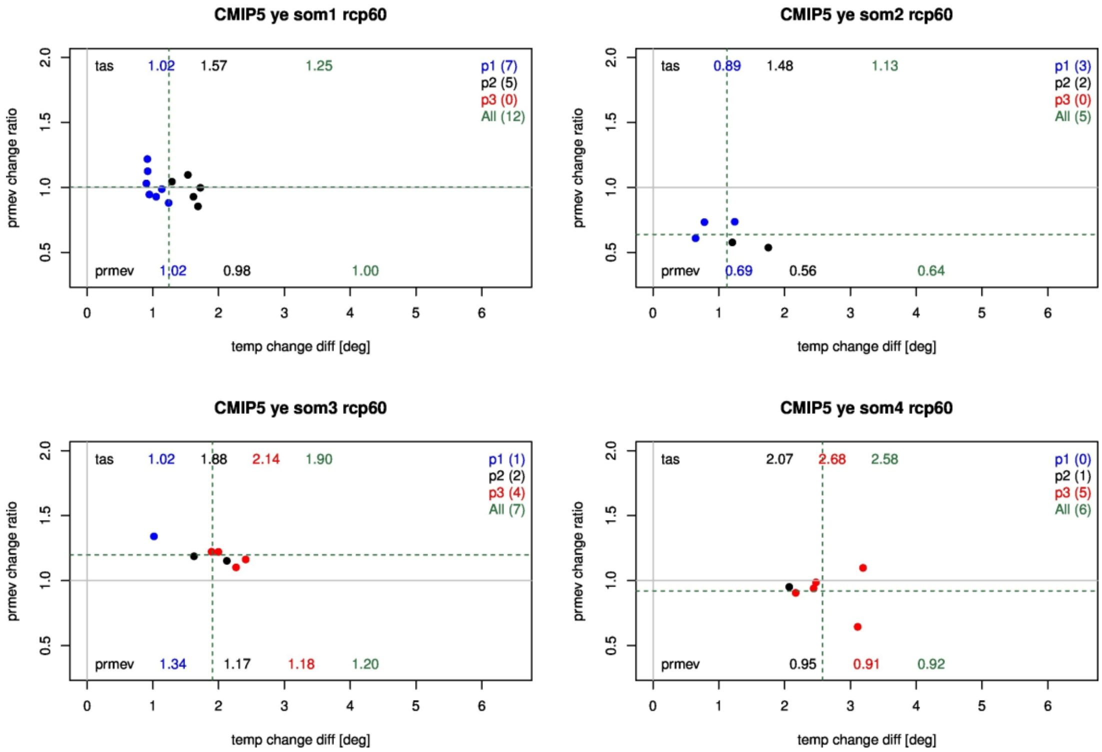


Figure VD14. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Vaal Domain under RCP6.0; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 10 projections in CMIP5 for RCP6.0.

Table VD6a. Scenarios for the year over the Vaal Domain under RCP6.0 based on Figure VD14 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
70	1→3	1.00ºC/1.00	1.50ºC/1.05	2.25ºC/1.20
30	2→4	1.00ºC/0.75	1.75ºC/0.75	2.75ºC/0.90

Summary: A limited number of projections, with some eliminated for producing unrealistic prmev values, provides a most likely increase in time in prmev. But to be treated with caution.

RCP6.0; temperature vs rainfall less evaporation

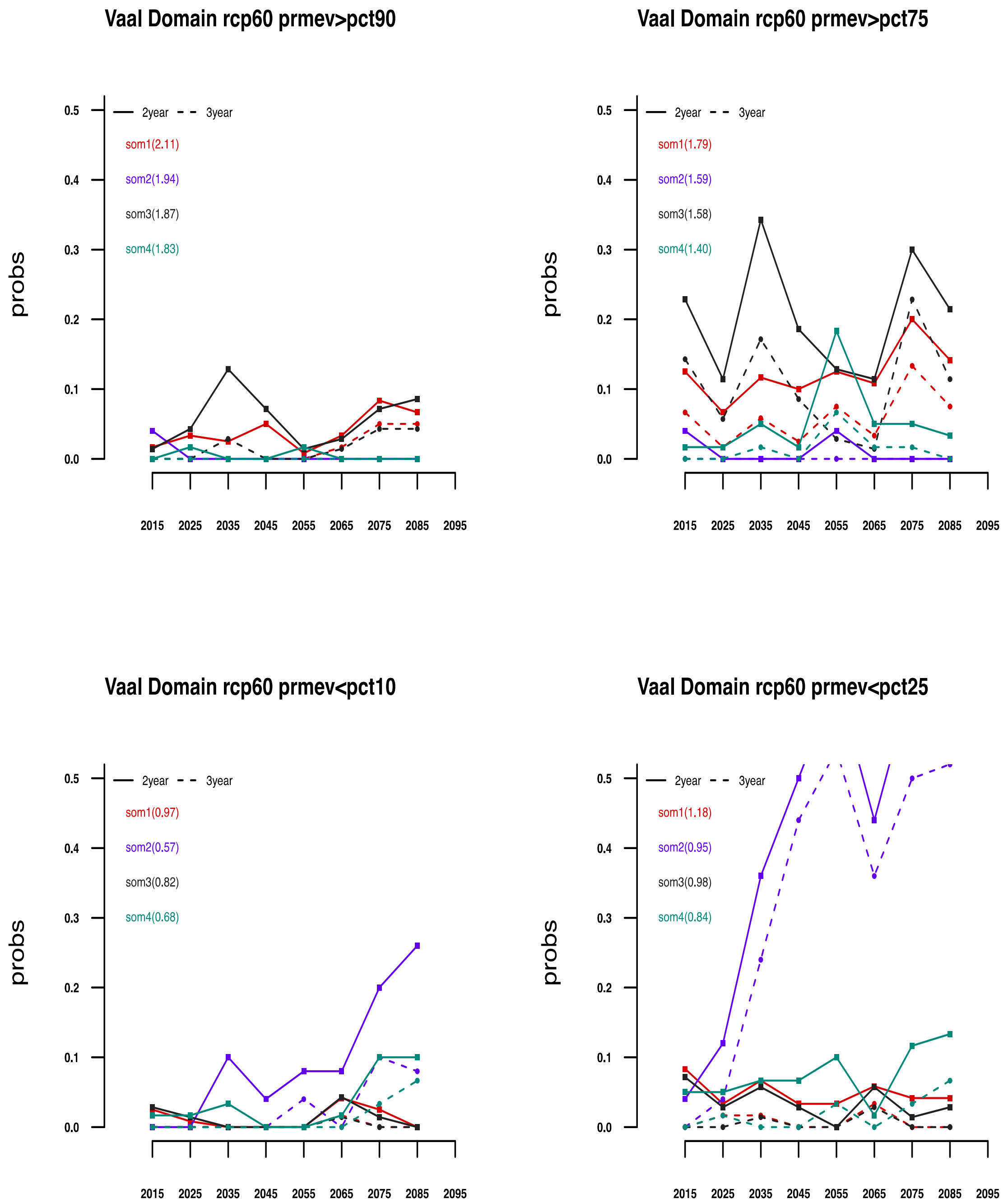


Figure VD15. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD14 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

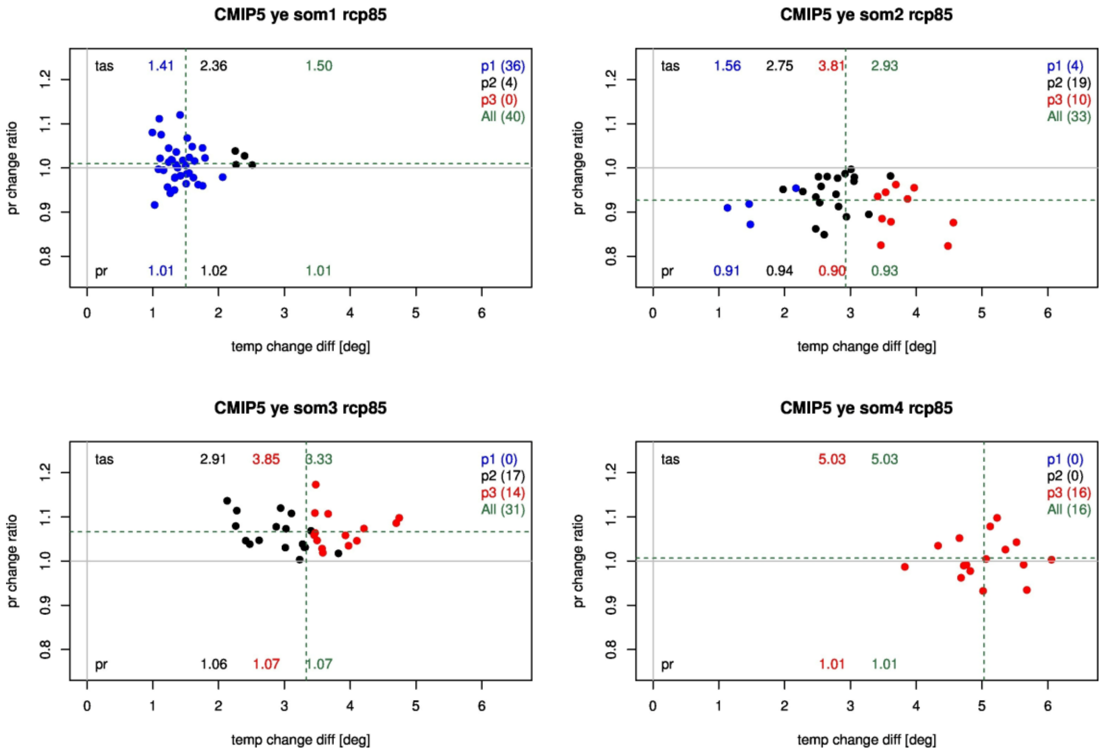


Figure VD16. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Vaal Domain under RCP8.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall/temperature projection relative to the base period of 1986-2005 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 (as a ratio - %); these are omitted in cases of charts with no projections within a particular time slot. There are 40 projections in CMIP5 for RCP8.5.

Table VD7a. Scenarios for the year over the Vaal Domain under RCP8.5 based on Figure VD16 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	1→2	1.50ºC/1.00	2.75ºC/0.95	4.00ºC/0.90
40	1→3	1.50ºC/1.00	2.75ºC/1.05	3.75ºC/1.05
15	1→4	1.50ºC/1.00	2.25ºC/1.00	5.00ºC/1.00

Summary: An unusual set of soms, with most 2040 projections within som1 plus a significant number of 2080 projections alone in som4, makes determining likelihoods difficult in this case. Weighting has been given to those soms with relatively large populations of 2065 projections, som2 and som3, with similar likelihoods and temperature futures, but opposite signs of rainfall changes. The final suggested scenario, using som4, has been given lower likelihood for its unusually high temperature increases but little change in rainfall.

RCP8.5; temperature vs rainfall

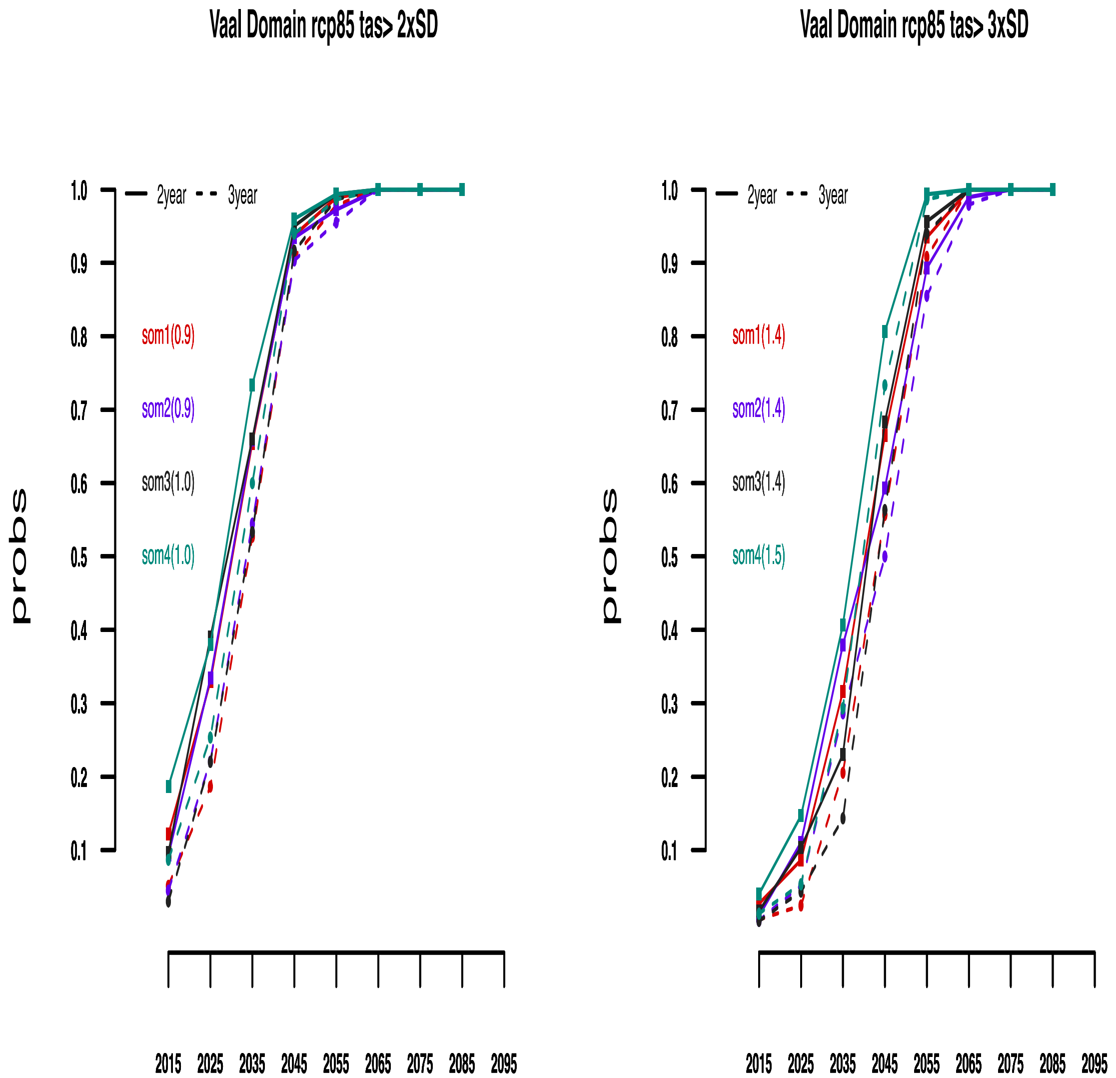


Figure VD17. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD16 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

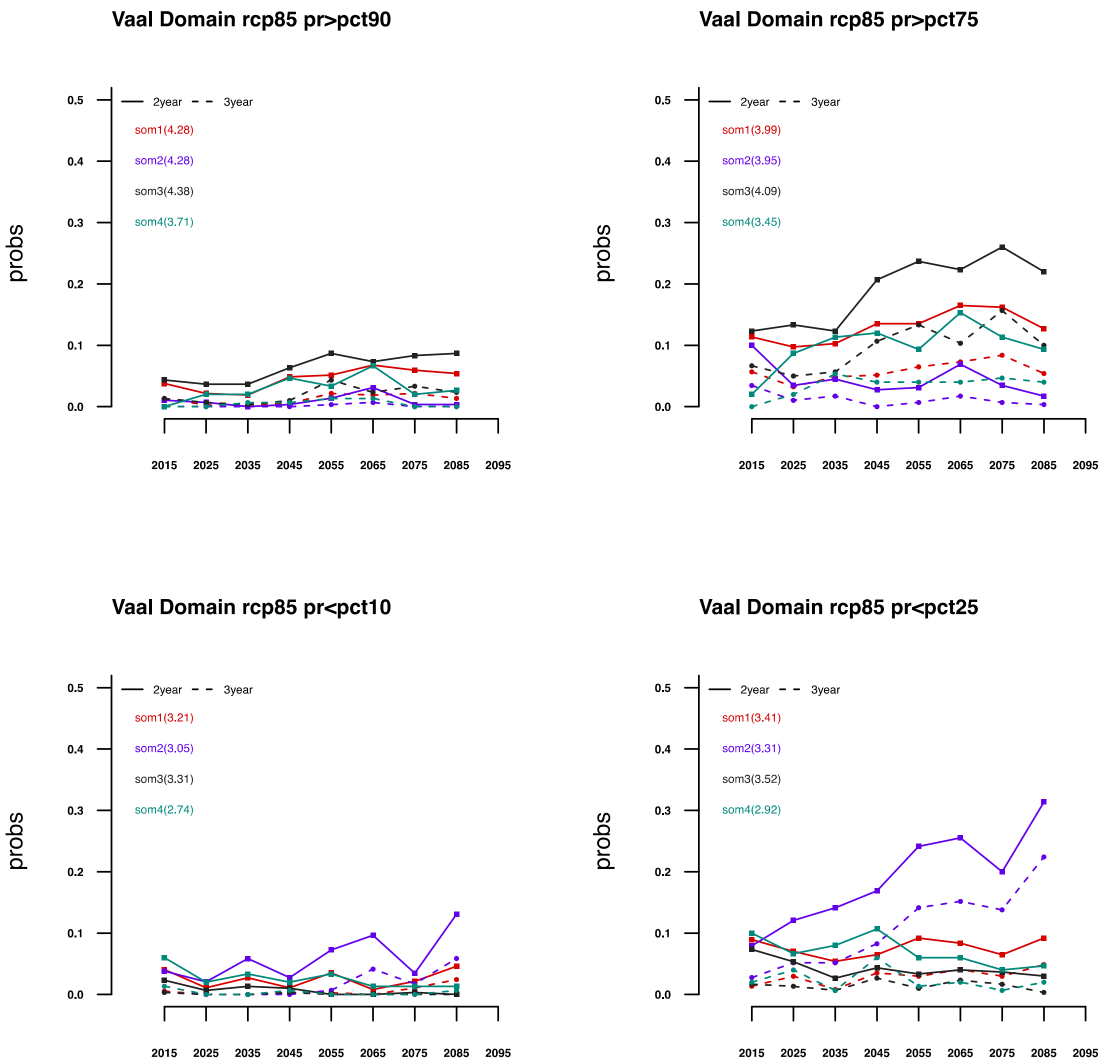


Figure VD18. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD16 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 less evaporation

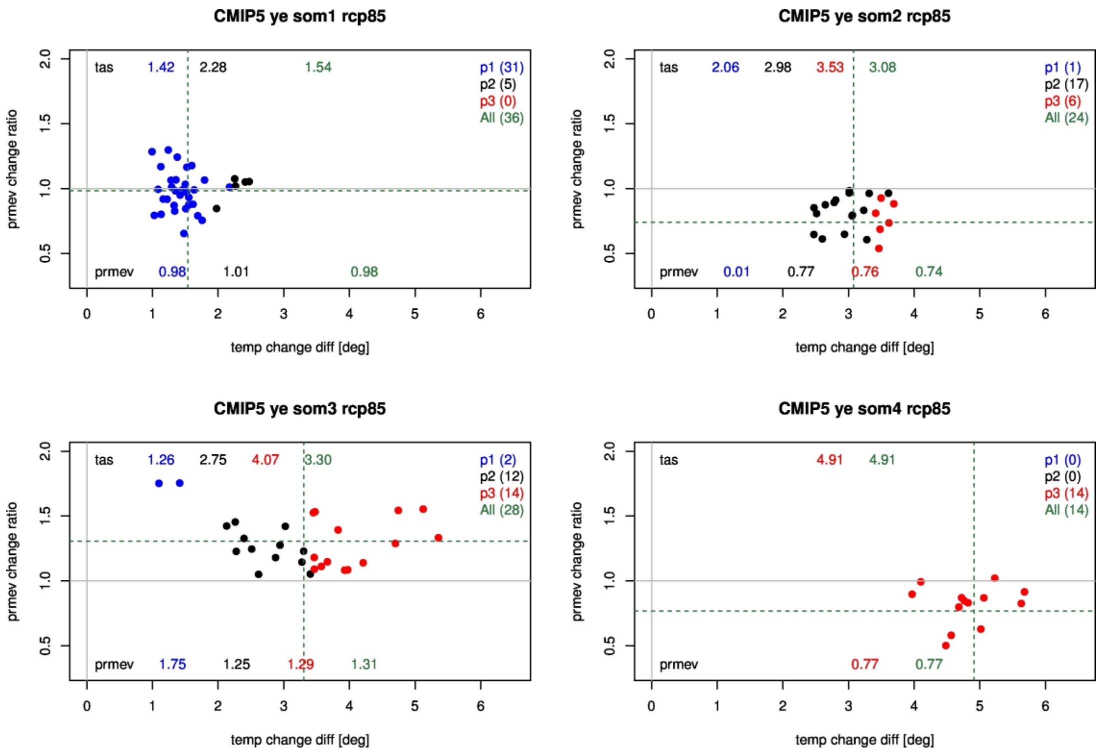


Figure VD19. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Vaal Domain under RCP8.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 VD8a. Scenarios for the year over the Vaal Domain under RCP8.5 based on Figure VD19 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
50	1→3	1.50ºC/1.00	2.75ºC/1.20	4.00ºC/1.30
35	1→2	1.50ºC/1.00	3.00ºC/0.80	3.50ºC/0.75
15	1→4	1.50ºC/1.00	2.50ºC/1.00	5.00ºC/0.80

Summary: Similar to the RCP8.5 soms against rainfall alone (see previous page), with most 2040 projections in som1 and some isolated 2080 projections in som4. Similar difficulties in assigning likelihoods, and no clear overall direction for prmev.

RCP8.5; temperature vs rainfall less evaporation

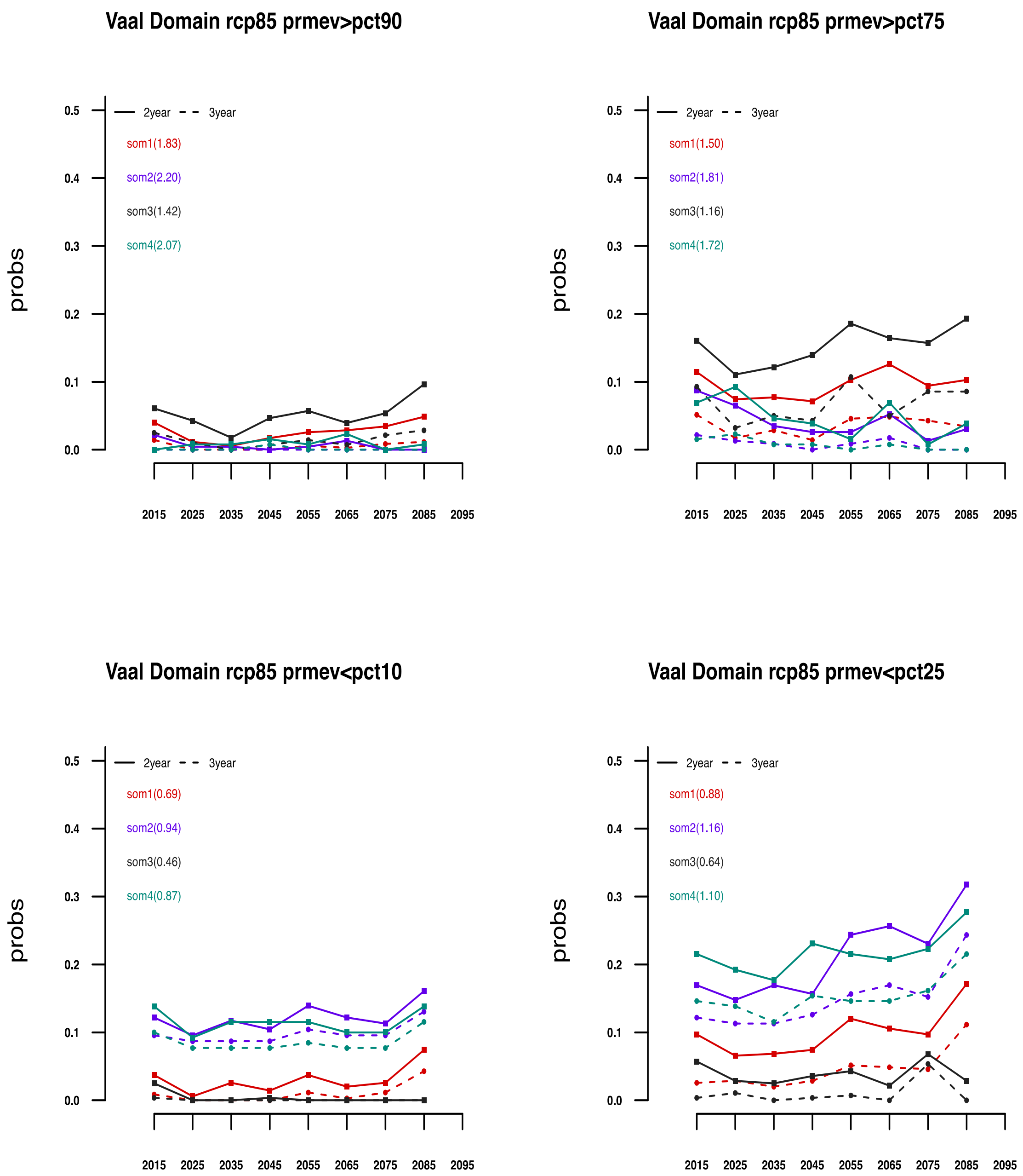


Figure VD20. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure VD19 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 less evaporation

Self-Organising Maps Results for the Confluence Domain

Introduction. Results are presented below for the analyses through self-organising maps (soms) for the Confluence 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; a limited number of rainfall less evaporation projections have been eliminated subjectively from the analyses where over-large changes in rainfall less evaporation results because of near-zero rainfall less evaporation values during the base period of 1986-2005.

Summary of results. Results for the Confluence Domain point to a marked weighting towards decreased rainfall and also rainfall less evaporation, although perhaps with lower likelihood for the latter. There is some consistency amongst the RCPs re the magnitude of future drying.

Temperature against rainfall. As might be expected, temperatures in the RCP scenarios increase with emissions, a rise that is, in general, similar or greater for the drier scenarios. There is a distinct weight towards reduced future rainfall for all RCPs that is reflected in the recommended scenarios where at best rainfall stays steady or decreases by 5%, or a little more. In the case of RCP8.5 only reductions in rainfall are present in the recommended scenarios together with greater temperature increases than in other RCPs.

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. Rainfall may increase by 10%, even 15% for RCP8.5, in the suggested extreme scenarios, but these increases need to be placed in the context of greater likelihoods overall for rainfall decreases; at best rainfall decreases by about 20% in the suggested extreme scenarios, although the 40% in that for RCP8.5 might be flagged as a warning.

Likelihoods of annual temperatures over two- and three-year periods exceeding two and three standard deviations calculated across the base period of 1986-2005 increase, naturally, with RCP, but vary also according to individual soms. Under RCP8.5 successive two and three year periods are almost certain by the 2050's for two standard deviations and by the 2060's for three standard deviations. By contrast, under RCP2.6 none of the soms produces probabilities above about 60% for two standard deviations over two-year periods, whereas for three standard deviations probabilities peak for just one som at around 40%. For RCP4.5 100% probabilities are reached only by the end of the century for two-year periods and for RCP6.0 by perhaps the 2080's over three-year periods by the end of the century.

Likelihoods of annual rainfall totals outside the 90th percentiles over 2 and 3 years remain mainly below 5%, perhaps decreasing towards the end of the century and towards the higher RCPs. However for totals outside the 10th percentile there is a definite increase in likelihoods as the century progresses, in one som under

RCP8.5 reaching almost 40% for two-year periods. There is a similar picture of future drying based on likelihoods outside the 25th and 75th percentiles, with values for the latter remaining below 10%, and perhaps declining in time, while there is an upward trend for the former (with the possible exception of RCP2.6) reaching over 50% for one RCP8.5 som over two years.

Temperature against rainfall less evaporation. There is perhaps a lesser likelihood of a decrease in rainfall less evaporation that in rainfall alone, presumably related in some manner to increased temperatures, but the overall weight remains for a decrease. The recommended scenario incorporating an increase under RCP8.5 needs treating with some caution.

In the extreme scenarios there are substantive decreases in rainfall less evaporation; the increased scenarios are not incompatible with CMIP5 but need to be considered in relation to the other results presented above.

Likelihoods of annual rainfall less evaporation amounts outside 90th percentile over 2 and 3 years, as similarly for rainfall totals, remain low, probably decreasing through the century; indeed, some of the values are 0%. Similarly, those for outside the 10th percentile remain in general relatively low, but higher and jump to almost 10% for some soms under RCP8.5. There do not appaer to be marked differences in similar likelihoods in terms of amounts outside the 25th and 75th percentiles in terms of RCP, but there does seem to be a slight weighting towards drier conditions. Overall the conclusions re rainfall less evaporation are that current distributions are more stable in time than those for rainfall alone.

Conclusions. In section 3 of the main report it was noted that the Confluence Domain sits at a location where ensemble means are consistent in suggesting decreases both in future rainfall and in future rainfall less evaporation; indeed, for the latter this Domain lies close to maximum projected decreases in a number of the means. It is also in an area for which temperature rises are close to the regional maximum according to the ensemble meas. Any adaptation planning certainly needs to consider these results.

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. It suggests a notably increased likelihood of decreased rainfall in both the temperature vs rainfall analyses and the temperature vs rainfall less evaporation. These differences in likelihoods 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 in 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. Frequencies of periods of relatively heavy and relative light rainfall, as assessed through the IAV analyses, indicate that the future climate will, on the whole, move towards drier conditions. But that conclusion is not replicated in the rainfall less evaporation likelihoods, which broadly suggest a continuation of current conditions. In other words, any adjustments in rainfall are balanced approximately by corresponding adjustments in evaporation.

RCP8.5; temperature vs rainfall less evaporation

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

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
75	1.25ºC/0.95	2.00ºC/0.90	2.25ºC/0.85
25	1.25ºC/1.00	1.50ºC/1.00	2.25ºC/1.00

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

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

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
60	1.25ºC/0.80	2.00ºC/0.80	2.25ºC/0.80
40	1.25ºC/1.00	1.50ºC/1.00	2.00ºC/1.05

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	1.50ºC/1.10	2.50ºC/1.10
Decreased	1.25ºC/0.70	2.00ºC/0.70	3.00ºC/0.70

Recommended Scenarios for the Confluence Domain based on RCP8.5

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
60	1.50ºC/0.95	3.00ºC/0.95	4.25ºC/0.95
40	1.50ºC/0.95	3.00ºC/0.85	4.75ºC/0.80

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

	2040	2065	2080
Increased	1.75ºC/1.15	3.50ºC/1.15	4.00ºC/1.15
Decreased	1.75ºC/0.80	3.25ºC/0.80	5.00ºC/0.80

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
75	1.50ºC/0.80	3.25ºC/0.60	5.00ºC/0.60
25	1.50ºC/0.80	2.75ºC/1.50	4.50ºC/1.70

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

	2040	2065	2080
Increased	1.50ºC/1.40	3.00ºC/1.40	4.25ºC/1.70
Decreased	1.75ºC/0.50	3.50ºC/0.40	5.50ºC/0.40

RCP8.5; temperature vs rainfall less evaporation

Scenarios from each RCP for the Confluence 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 15 projections

	%		2040	2065	2080		%		2040	2065	2080
1	30	1	1.00ºC/1.00	1.00ºC/1.00	1.00ºC/1.00		40	1	1.00ºC/1.00	1.00ºC/0.95	0.75ºC/1.05
2	30	2	1.50ºC/0.95	1.75ºC/0.95	1.75ºC/0.95		30	4	1.25ºC/0.70	1.50ºC/0.70	1.25ºC/0.70
3	30	3	1.25ºC/0.85	1.50ºC/0.85	1.75ºC/0.80		20	3	1.75ºC/0.80	2.00ºC/0.70	2.00ºC/0.75
4	10	4	1.00ºC/0.95	1.00ºC/0.95	1.00ºC/0.95		10	2	1.50ºC/1.20	1.50ºC/1.25	1.75ºC/1.75

Summary: Whereas the weight of suggested scenarios in TR is towards no change or a decrease in rainfall, in TRLE there is rough equality between increased and decreased water availability. Presumably this an indication of the effects of temperature changes on evaporation.

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	1.25ºC/1.05	1.50ºC/1.05	1.50ºC/1.05		1.00ºC/1.10	1.50ºC/1.10	1.50ºC/1.10
Decreased	1.25ºC/0.85	1.75ºC/0.85	2.00ºC/0.80		1.00ºC/0.75	1.50ºC/0.70	1.75ºC/0.60

RCP4.5 – 38 and 32 projections

	%		2040	2065	2080		%		2040	2065	2080
1	60	1→4	1.25ºC/1.00	2.00ºC/1.00	2.25ºC/0.95		50	1→3	1.25ºC/1.05	2.00ºC/0.90	2.00ºC/0.90
2	40	2→3	1.50ºC/0.85	2.25ºC/0.85	2.75ºC/0.85		50	2→4	1.50ºC/0.50	2.50ºC/0.70	2.75ºC/0.70

Summary: Both suggested scenarios offer minimal comfort for retaining current water availability levels under RCP4.5. Even were the rainfall decrease to be limited as in the suggested scenario with highest likelihood in TR, results from TRLE suggest likely future 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

RCP8.5; temperature vs rainfall less evaporation

	2040	2065	2080		2040	2065	2080
Increased	1.25ºC/1.10	1.50ºC/1.15	2.25ºC/1.10		1.00ºC/1.50	2.00ºC/1.50	2.50ºC/1.50
Decreased	1.50ºC/0.85	2.50ºC/0.80	3.00ºC/0.75		1.50ºC/0.50	2.00ºC/0.50	2.75ºC/0.50

RCP6.0 – 15 and 7 projections

	%		2040	2065	2080		%		2040	2065	2080
1	60	1→3	1.25ºC/0.95	2.00ºC/0.95	2.25ºC/1.00		60	1→3	1.25ºC/0.90	1.50ºC/0.95	2.50ºC/1.10
2	40	1→2→4	1.25ºC/0.95	2.00ºC/0.85	3.00ºC/0.85		40	1→2→4	1.25ºC/0.90	2.00ºC/0.75	3.00ºC/0.80

Summary: Caution is required with the TRLE results as only 7 projections remained after those with unrealistic changes in prmev were removed. Otherwise there is reasonable consistency between results in TR and TRLE, with an overall weighting towards decreased water availability. The same caution applies also to the extreme scenarios below.

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/1.00	1.50ºC/1.00	2.00ºC/1.05		1.00ºC/1.00	1.50ºC/1.05	3.00ºC/1.10
Decreased	1.00ºC/0.85	2.00ºC/0.80	3.00ºC/0.80		1.25ºC/0.75	2.00ºC/0.70	3.00ºC/0.70

RCP8.5

	%		2040	2065	2080		%		2040	2065	2080
1	60	1→3	1.50ºC/0.95	3.00ºC/0.95	4.25ºC/0.95		75	2→3→4	1.50ºC/0.80	3.25ºC/0.60	5.00ºC/0.60
2	40	1→2→4	1.50ºC/0.95	3.00ºC/0.85	4.75ºC/0.80		25	2→1	1.50ºC/0.80	2.75ºC/1.50	4.50ºC/1.70

Summary: There is little succour in these results with the predominant weighting being towards reductions in water availability. However the lower likelihood suggested scenario in TRLE offers some indication of possible future increases 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	3.50ºC/1.15	4.00ºC/1.15		1.50ºC/1.40	3.00ºC/1.40	4.25ºC/1.70
Decreased	1.75ºC/0.80	3.25ºC/0.80	5.00ºC/0.80		1.75ºC/0.50	3.50ºC/0.40	5.50ºC/0.40

RCP2.6: temperature vs rainfall

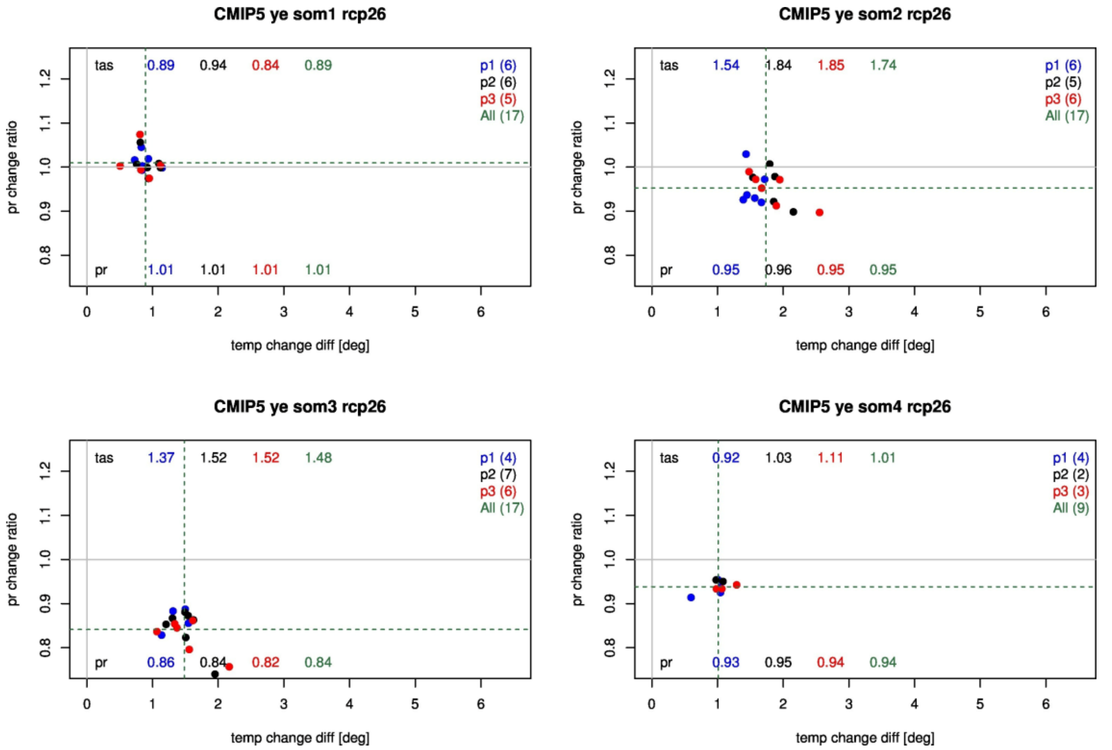


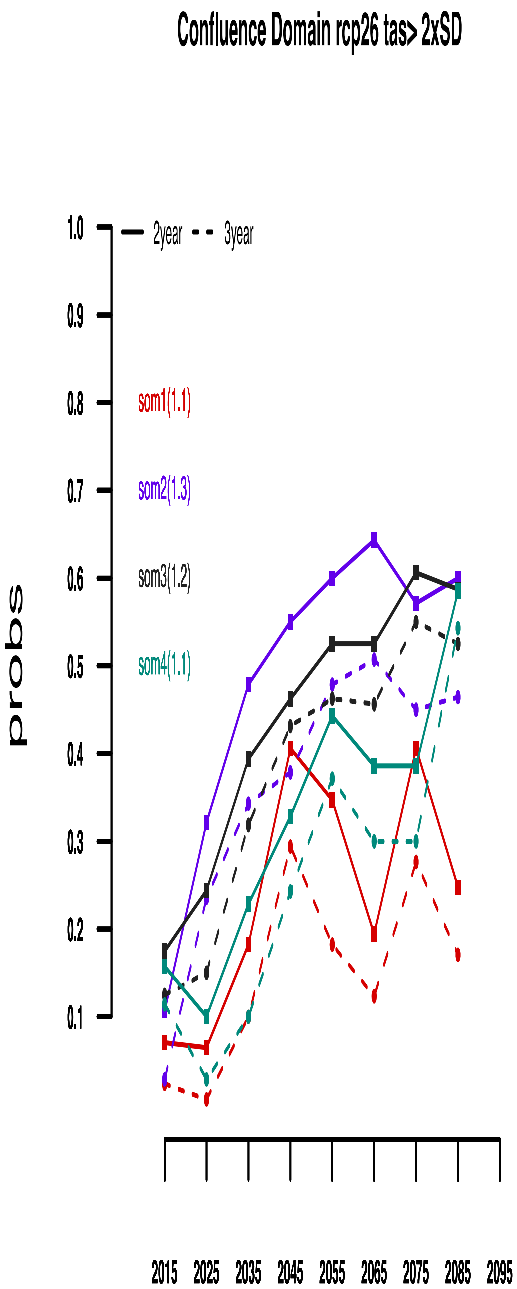
Figure CD21. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Confluence Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 Confluence 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
30	1	1.00ºC/1.00	1.00ºC/1.00	1.00ºC/1.00
30	2	1.50ºC/0.95	1.75ºC/0.95	1.75ºC/0.95
30	3	1.25ºC/0.85	1.50ºC/0.85	1.75ºC/0.80
10	4	1.00ºC/0.95	1.00ºC/0.95	1.00ºC/0.95

Summary: All four soms are occupied by similar numbers of projections from all three periods and appear to form four separate scenarios with similar likelihoods. The weight of these scenarios tends towards a reduction in rainfall. NB: Ideal likelihoods might be 28:28:28:16 but rounding to 5% unweights the likelihood of the least likely scenario.

RCP2.6: temperature vs rainfall



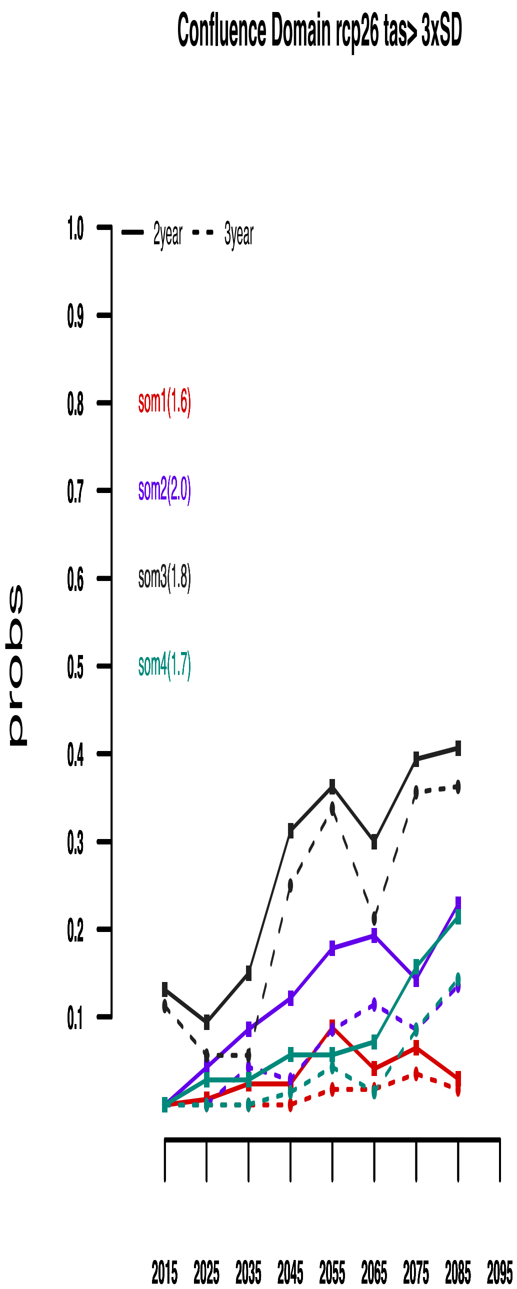


Figure CD22. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. 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.

RCP2.6: temperature vs rainfall

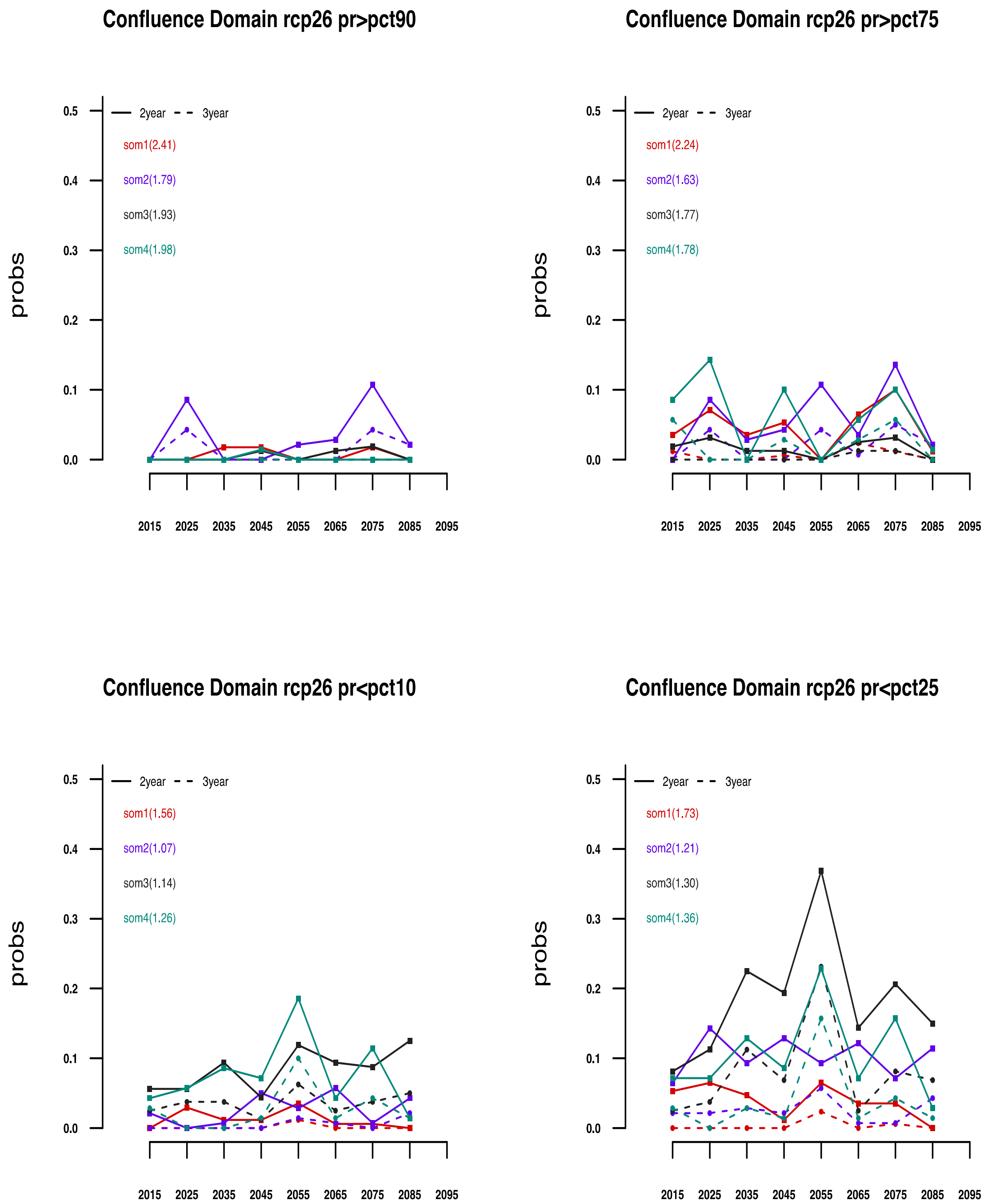


Figure CD23. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. 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

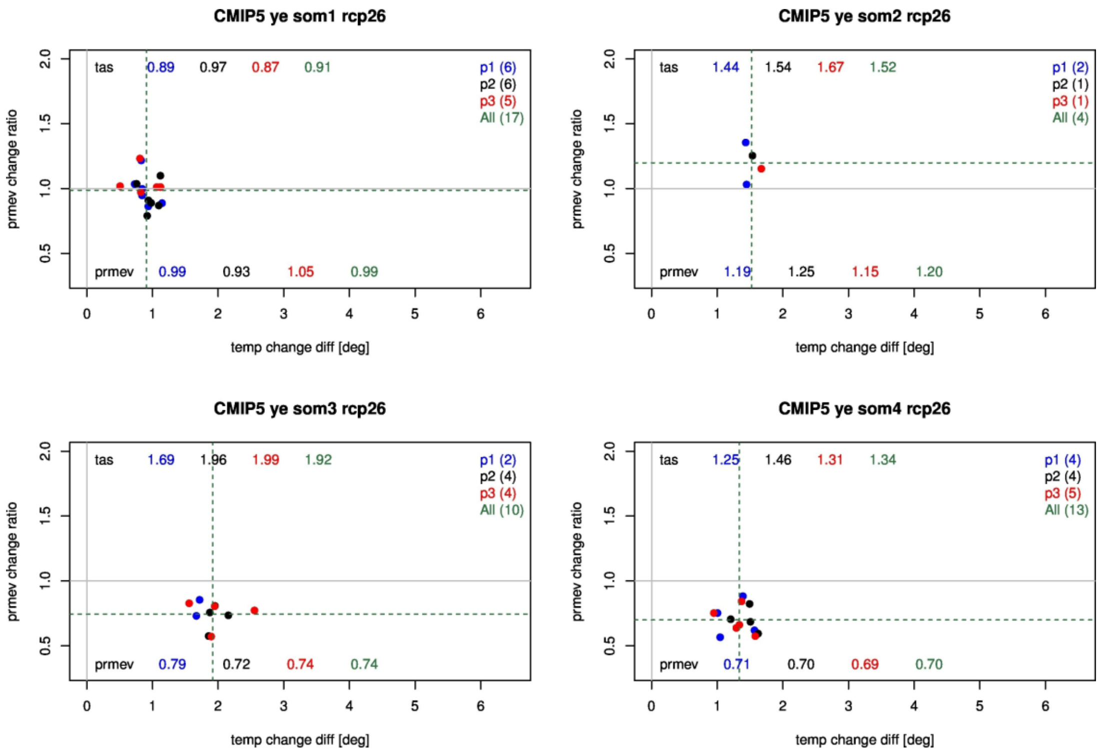


Figure CD4. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Confluence Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 15 projections in CMIP5 for RCP2.6.

Table CD1a. Scenarios for the year over the Confluence 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
40	1	1.00ºC/1.00	1.00ºC/0.95	0.75ºC/1.05
30	4	1.25ºC/0.70	1.50ºC/0.70	1.25ºC/0.70
20	3	1.75ºC/0.80	2.00ºC/0.70	2.00ºC/0.75
10	2	1.50ºC/1.20	1.50ºC/1.25	1.75ºC/1.75

Summary: Four separate scenarios, but the only one suggesting substantial future increases in water availability has the lowest likelihood. Marked decreases in water availability have been suggested as having a combined likelihood of about 50%, with little change at about 40%.

RCP2.6: temperature vs rainfall less evaporation

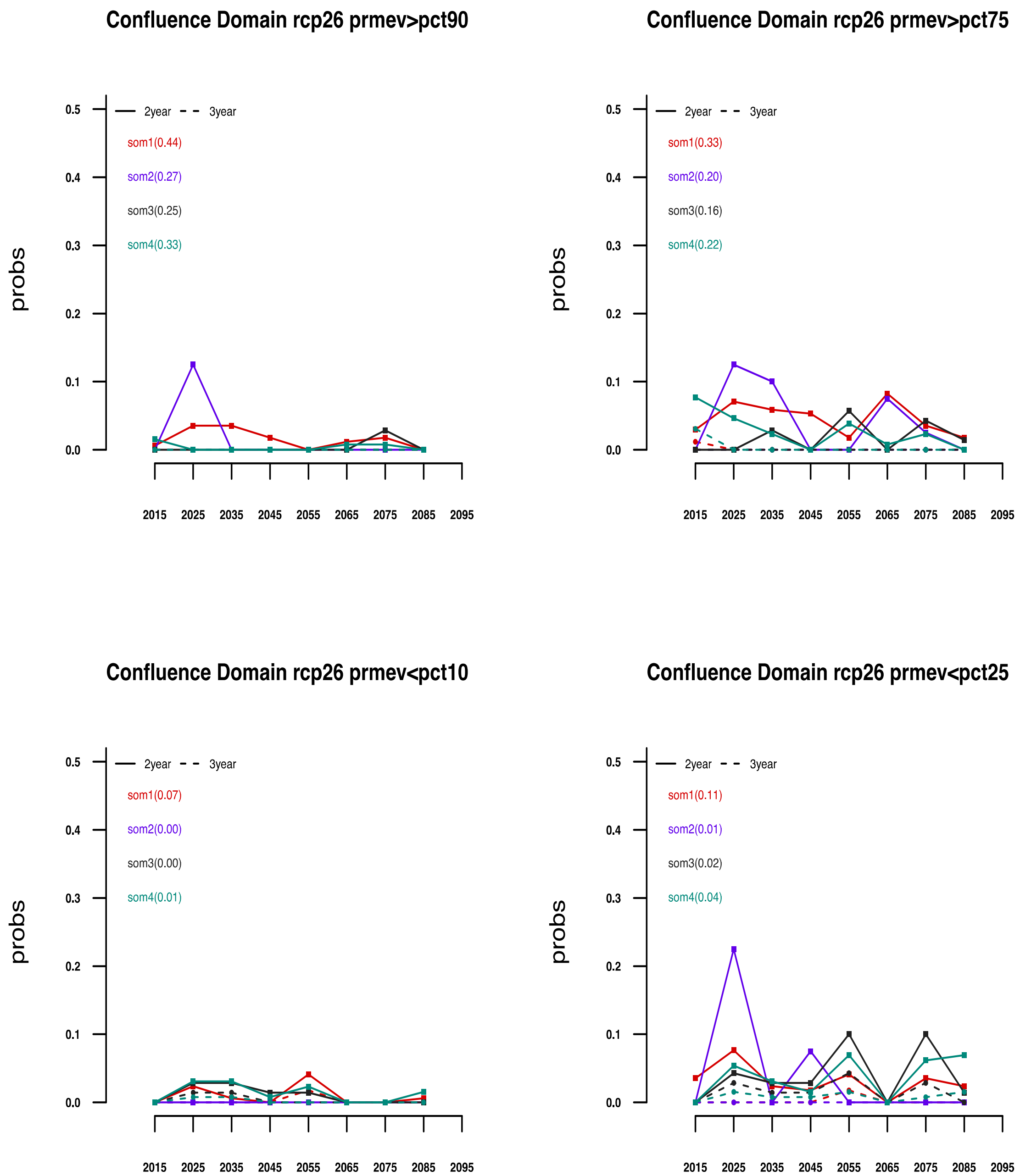


Figure CD5. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure CD4 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

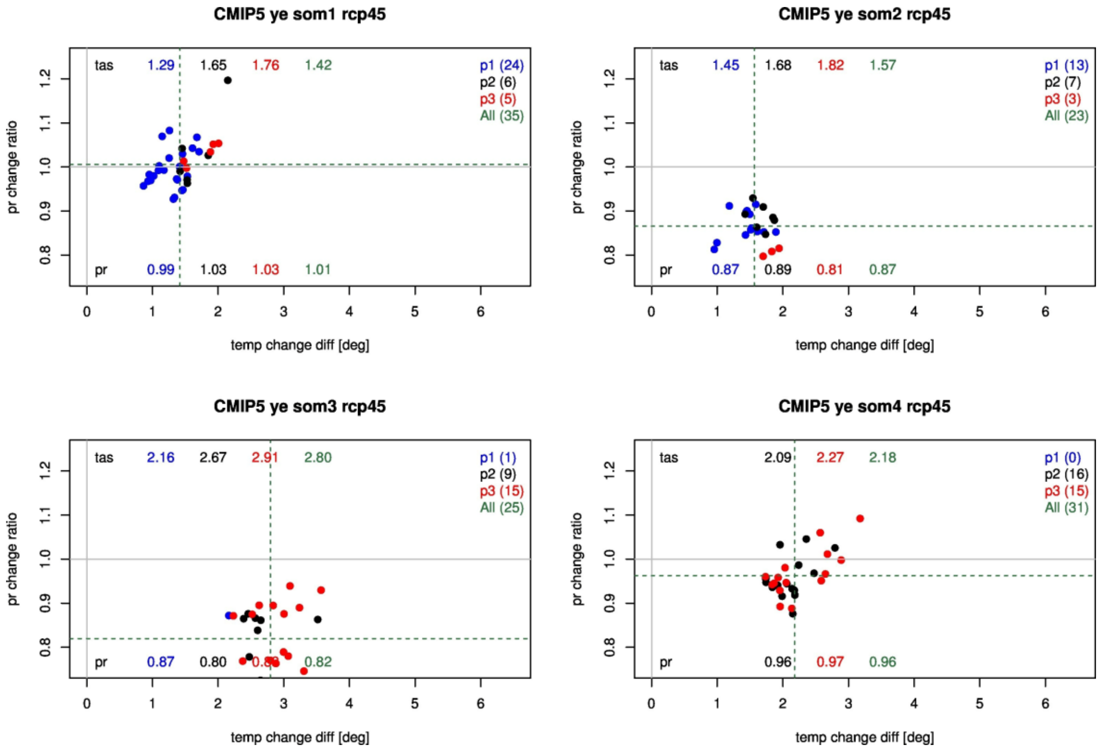


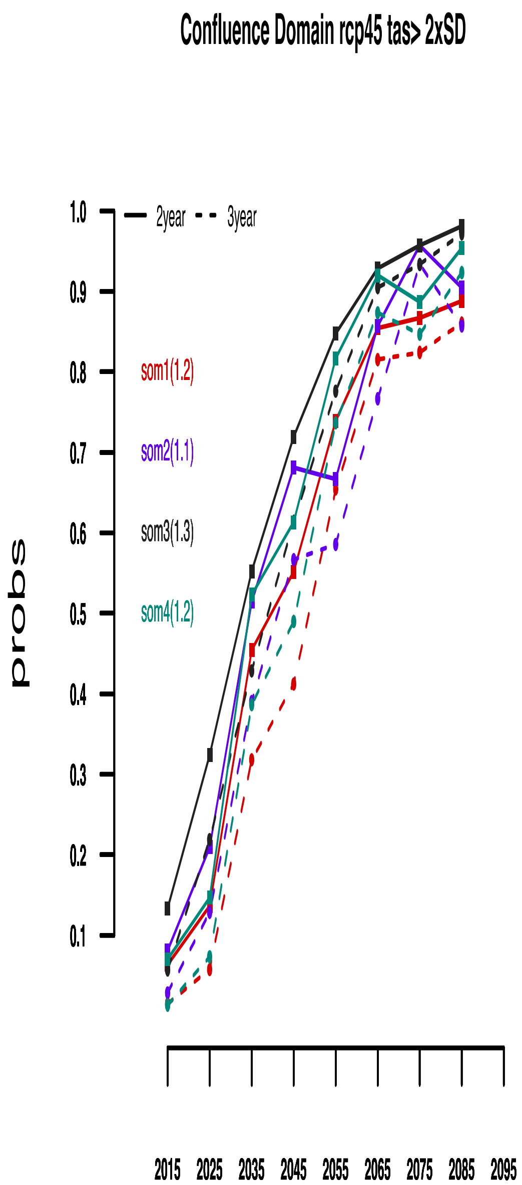
Figure CD6. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Confluence Domain under RCP4.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 Confluence 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
60	1→4	1.25ºC/1.00	2.00ºC/1.00	2.25ºC/0.95
40	2→3	1.50ºC/0.85	2.25ºC/0.85	2.75ºC/0.85

Summary: Certainly, the majority of projections indicate varying degrees of reductions in future rainfall. Nevertheless, the scenario with highest estimated likelihood retains current levels of rainfall through much of the century.

RCP4.5: temperature vs rainfall



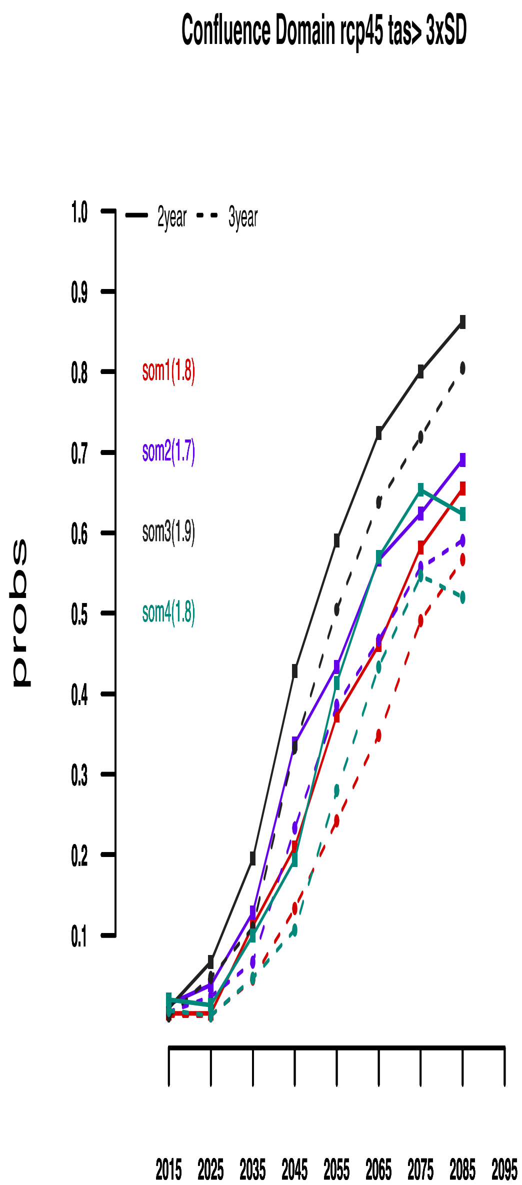


Figure CD7. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. 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

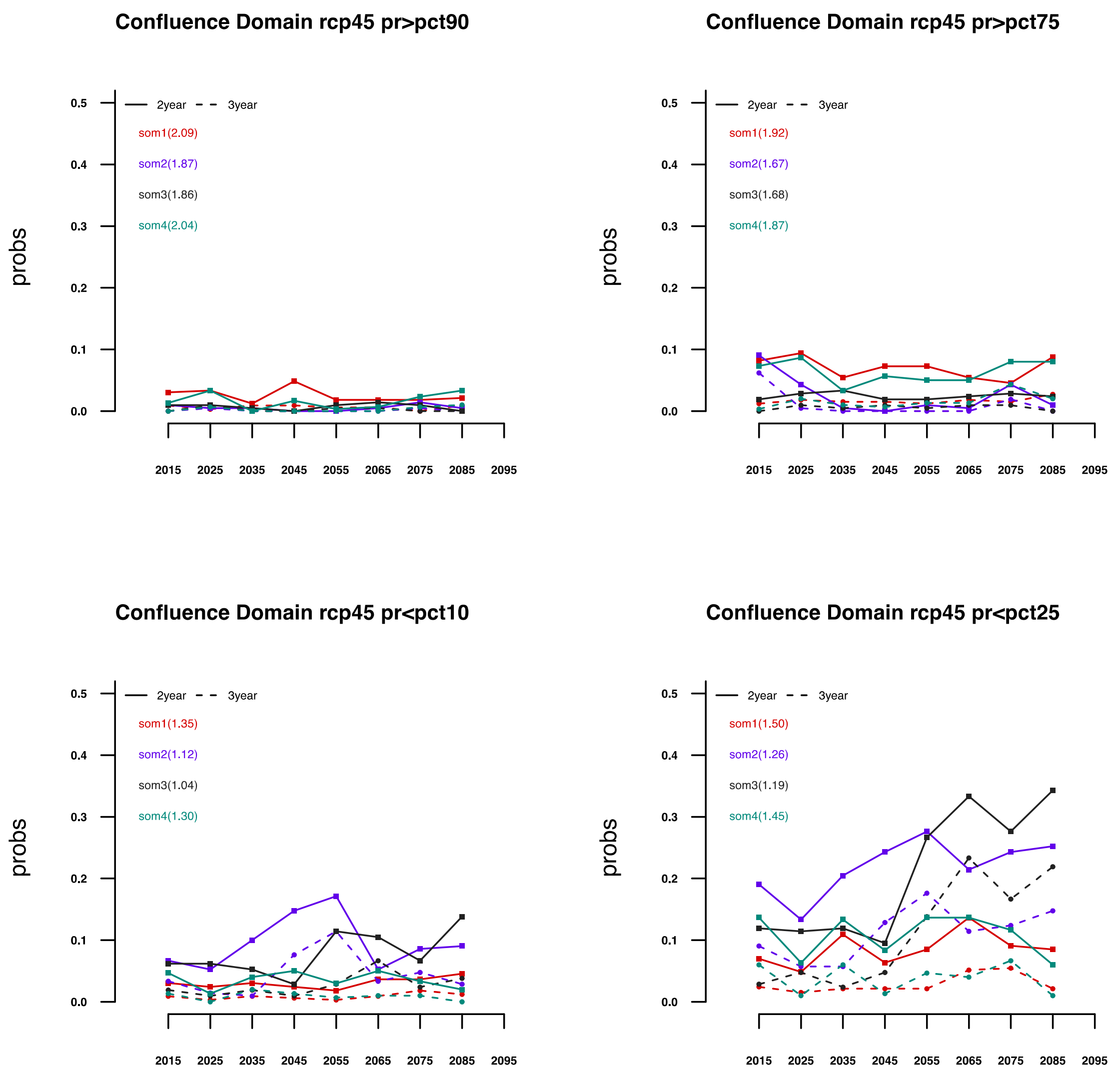


Figure CD8. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. 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

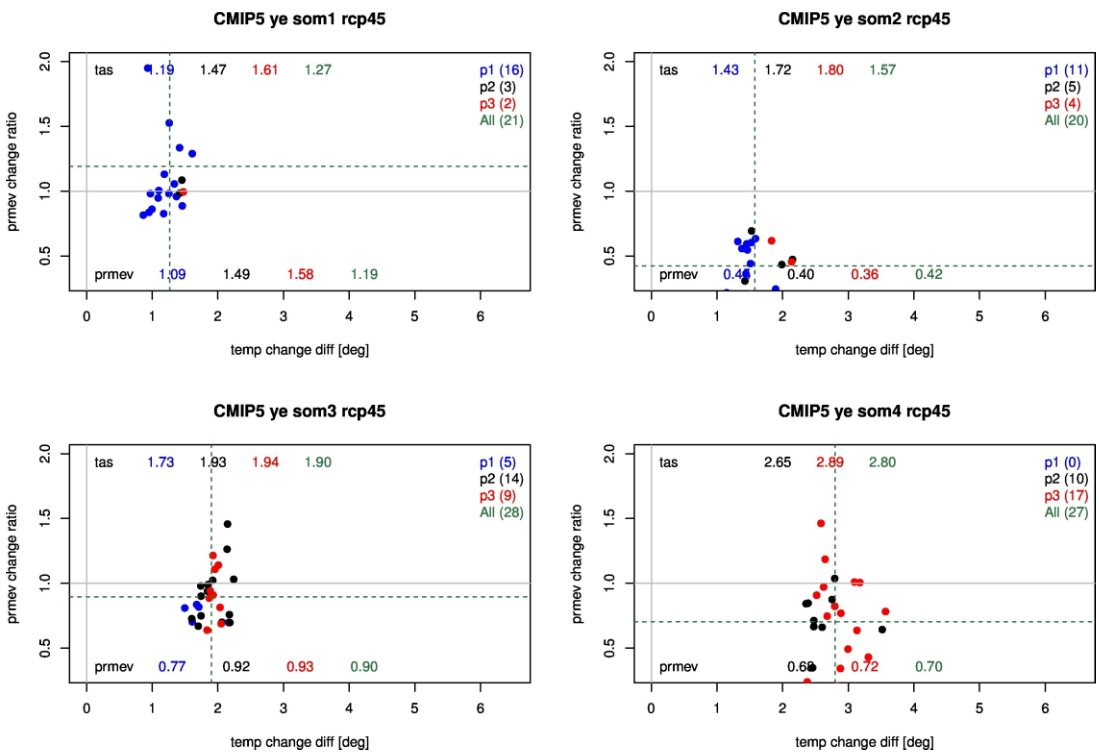


Figure CD9. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Confluence Domain under RCP4.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 RCP4.5.

Table CD4a. Scenarios for the year over the Confluence 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
50	1→3	1.25ºC/1.05	2.00ºC/0.90	2.00ºC/0.90
50	2→4	1.50ºC/0.50	2.50ºC/0.70	2.75ºC/0.70

Summary: Two suggested scenarios with roughly equal likelihoods, both ultimately leading to a reduction in water resources. The lower one in Table CD4a appears to be a valid interpretation of the soms results but does suggest a rather rapid decrease in water availability in the near future: caution needs to be taken with this result.

RCP4.5: temperature vs rainfall less evaporation

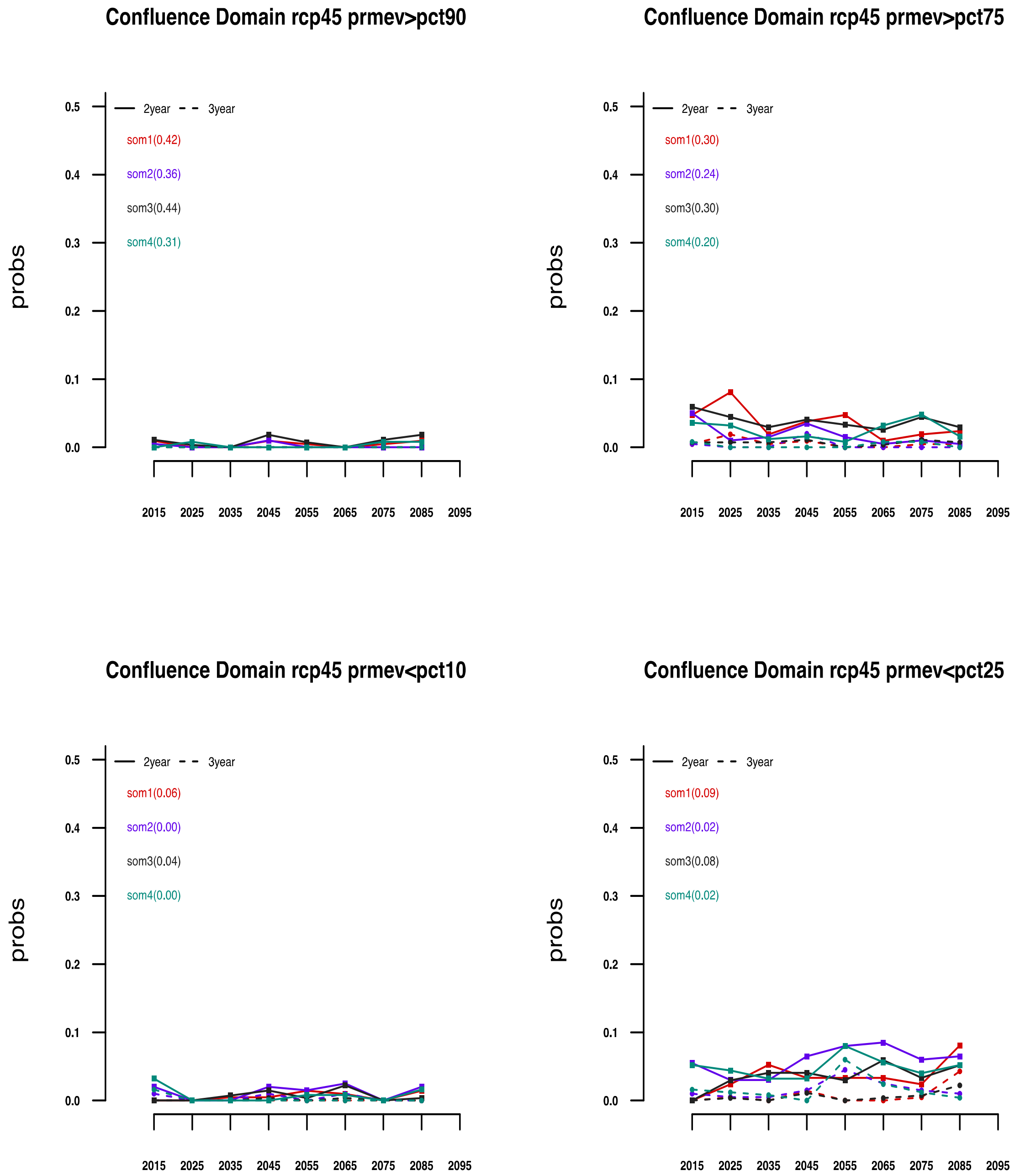


Figure CD10. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. 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

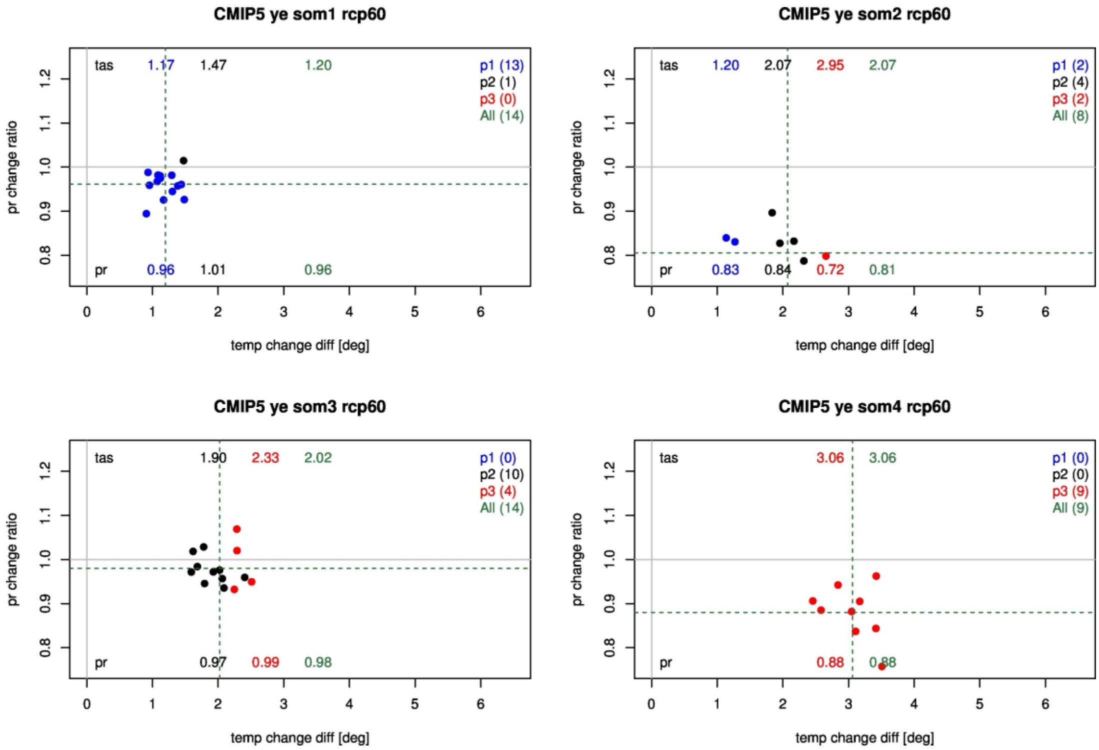


Figure CD11. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Confluence Domain under RCP6.0 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 Confluence 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
60	1→3	1.25ºC/0.95	2.00ºC/0.95	2.25ºC/1.00
40	1→2→4	1.25ºC/0.95	2.00ºC/0.85	3.00ºC/0.85

Summary: Most 2040 projections lie within som1, hence both suggested scenarios begin there. Few projections occur any indication of rainfall increases, hence the suggested scenarios are weighted to a decrease.

RCP6.0: temperature vs rainfall

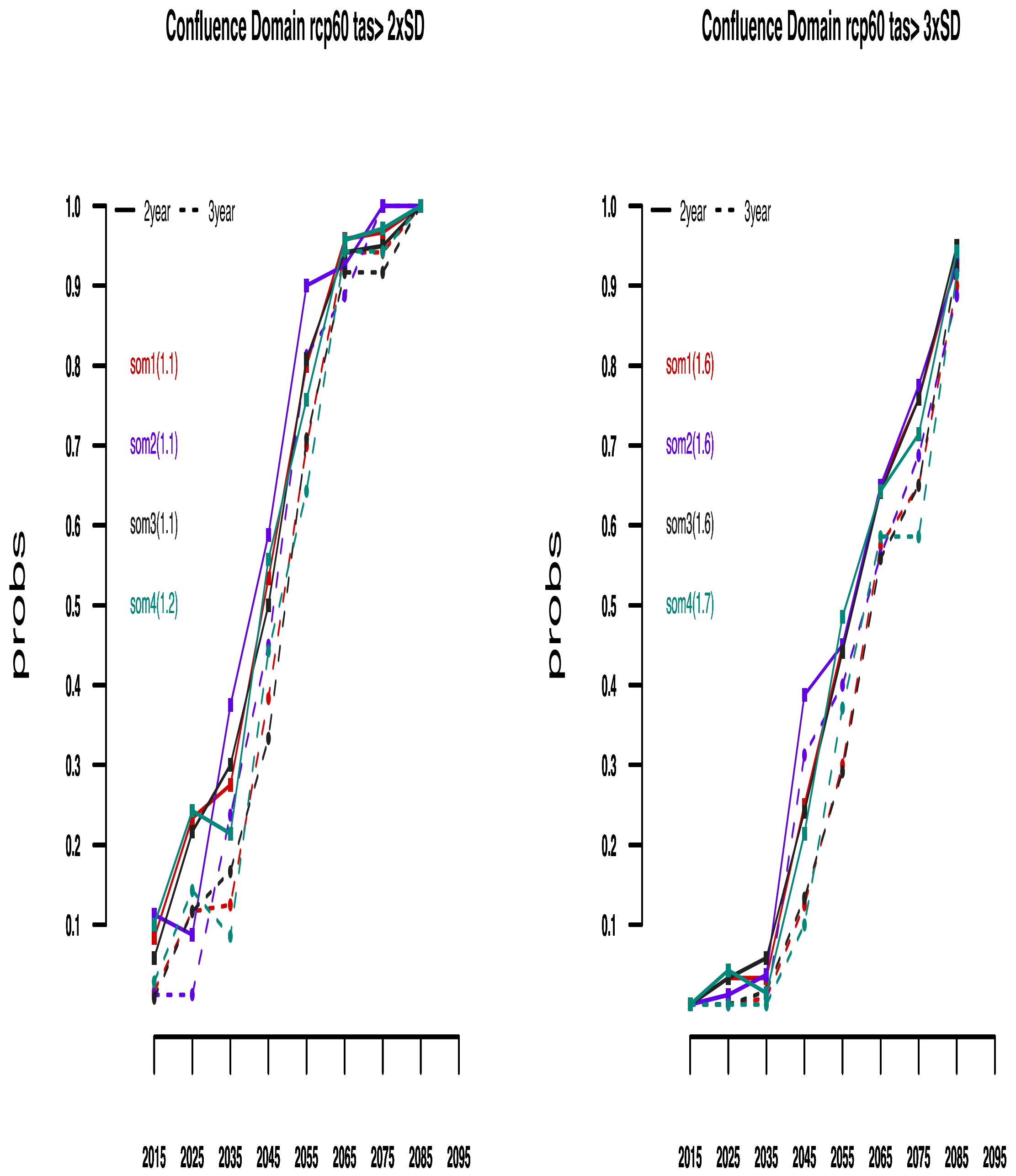


Figure CD12. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. 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.

RCP6.0: temperature vs rainfall

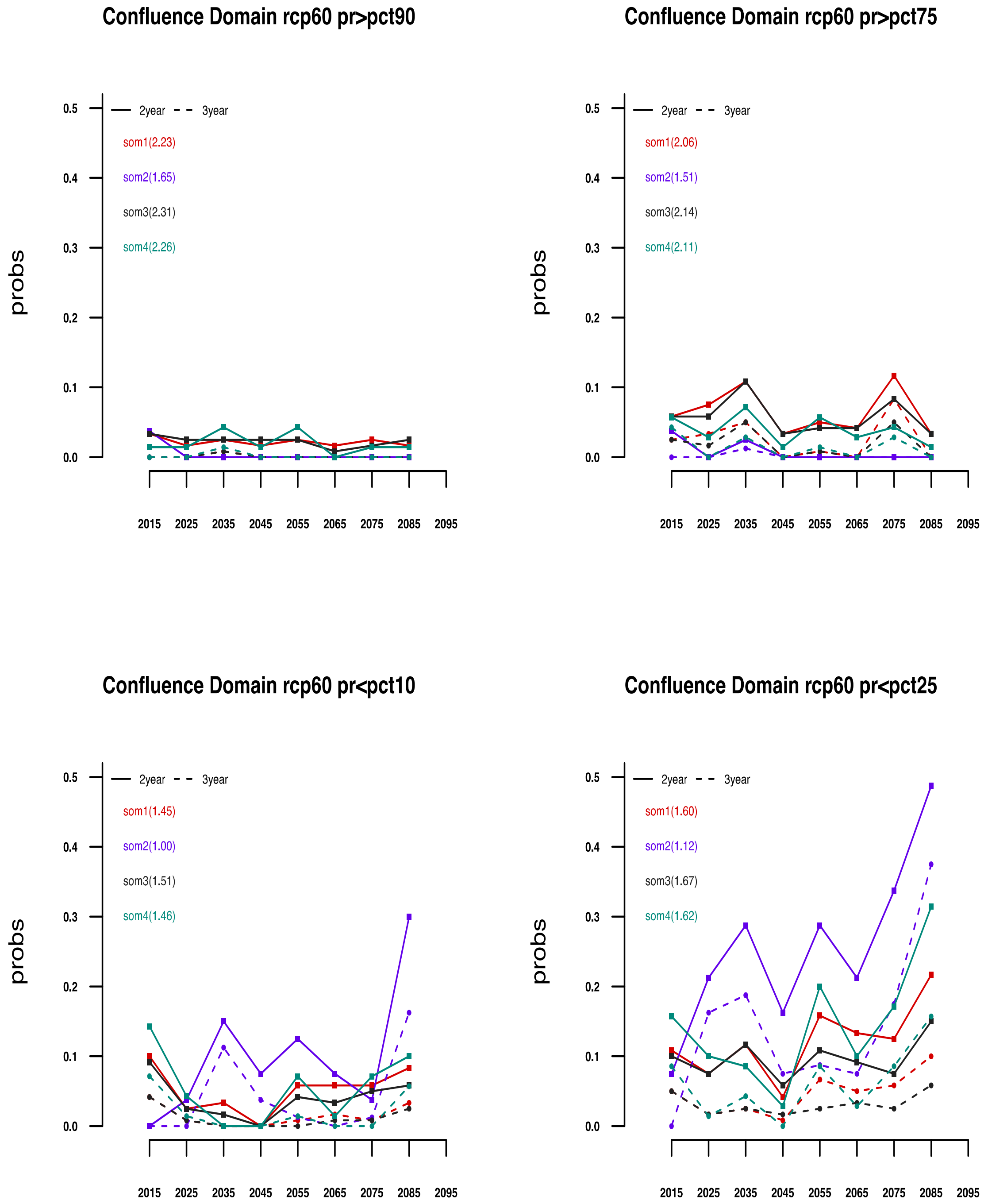


Figure CD13. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. 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.

RCP6.0: temperature vs rainfall less evaporation

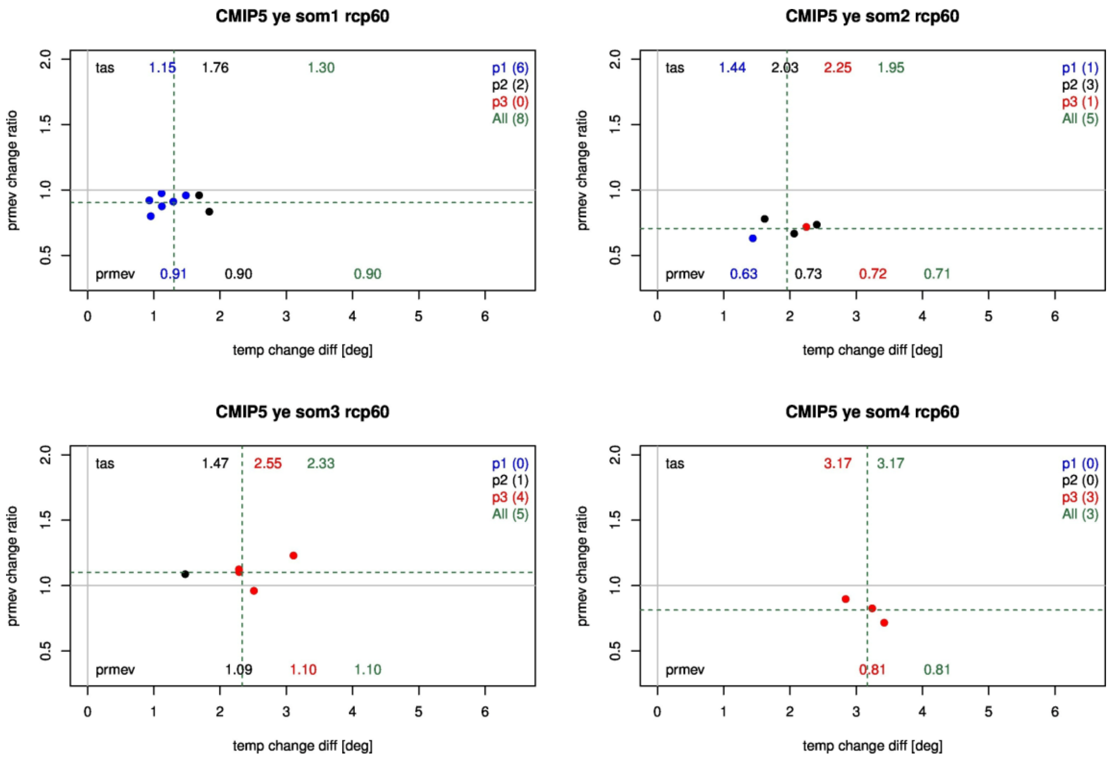


Figure CD14. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Confluence Domain under RCP6.0; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 7 projections in CMIP5 for RCP6.0.

Table CD3a. Scenarios for the year over the Confluence 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
60	1→3	1.25ºC/0.90	1.50ºC/0.95	2.50ºC/1.10
40	1→2→4	1.25ºC/0.90	2.00ºC/0.75	3.00ºC/0.80

Summary: With only 7 projections left after those with unrealistic prmev ratios were discarded this set of results needs to be treated with caution. Those projections left are weighted towards future reductions in water availability.

RCP6.0: temperature vs rainfall less evaporation

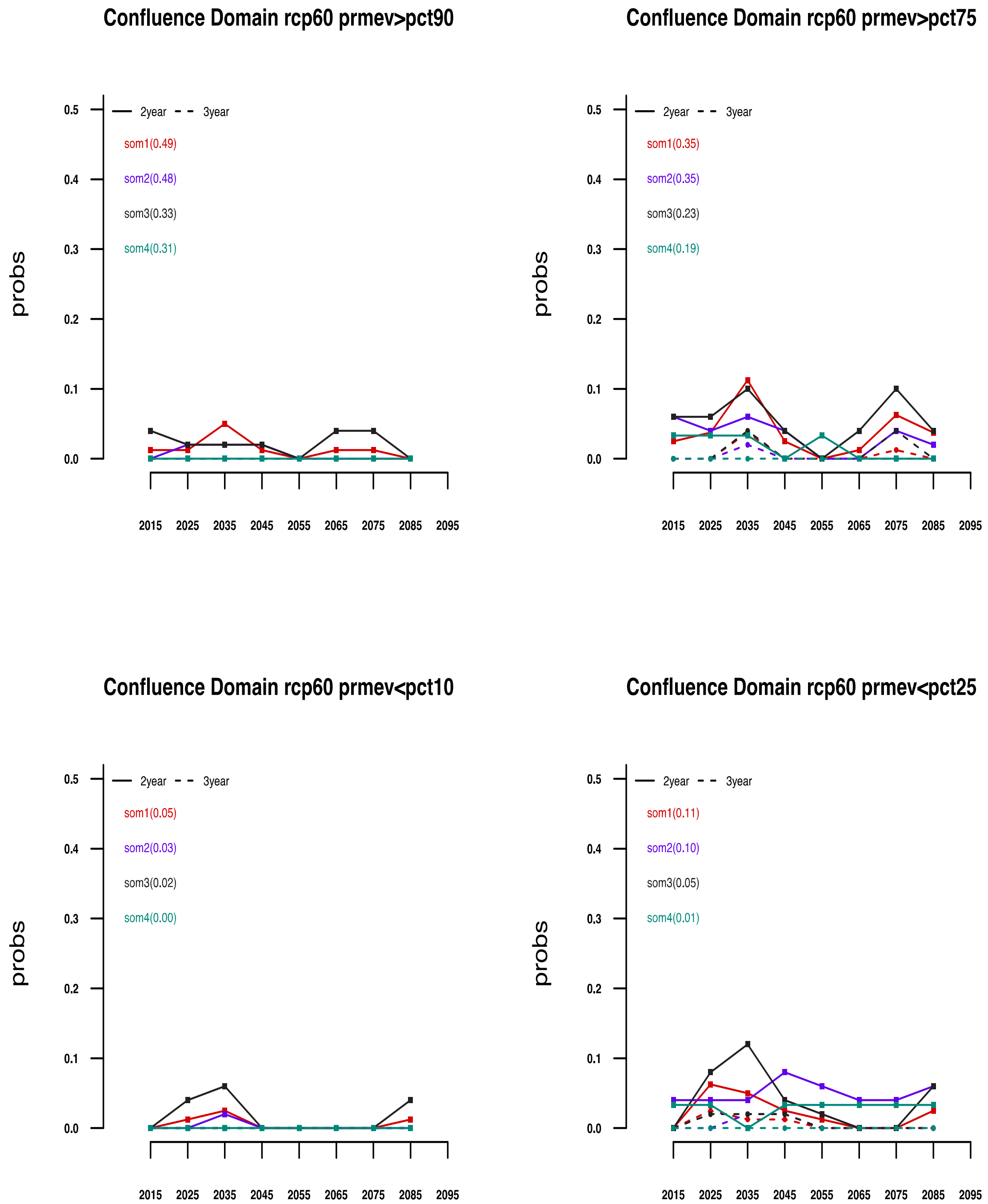


Figure CD124. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. 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.

RCP8.5: temperature vs rainfall

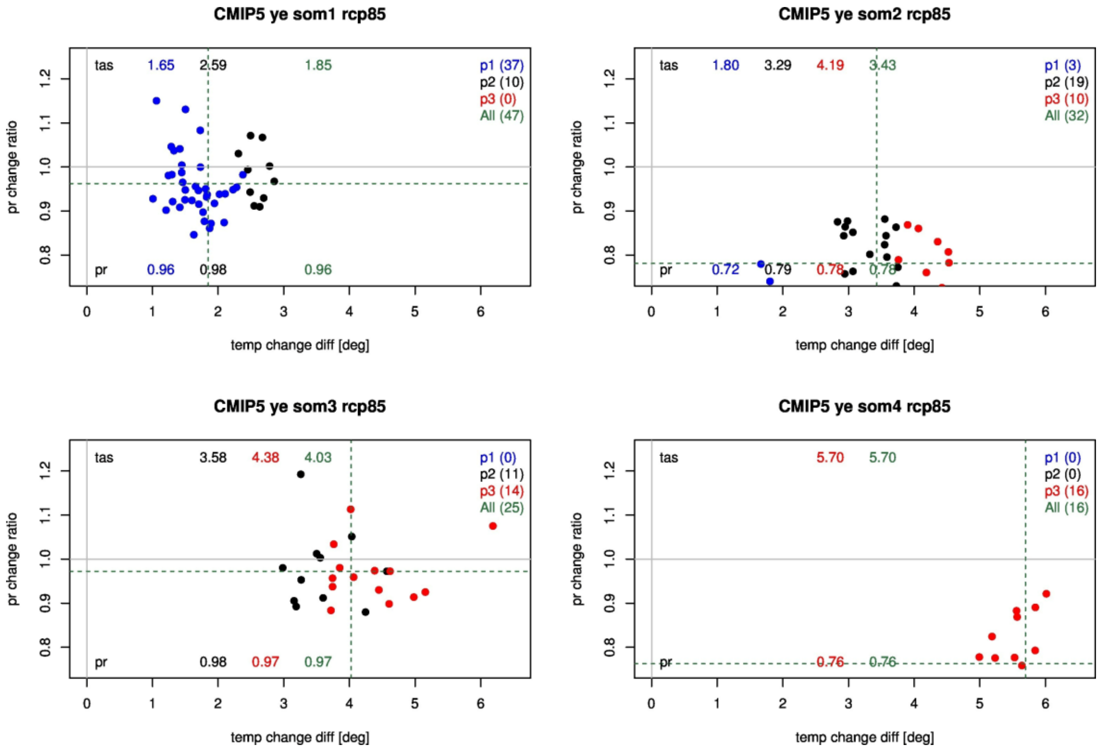


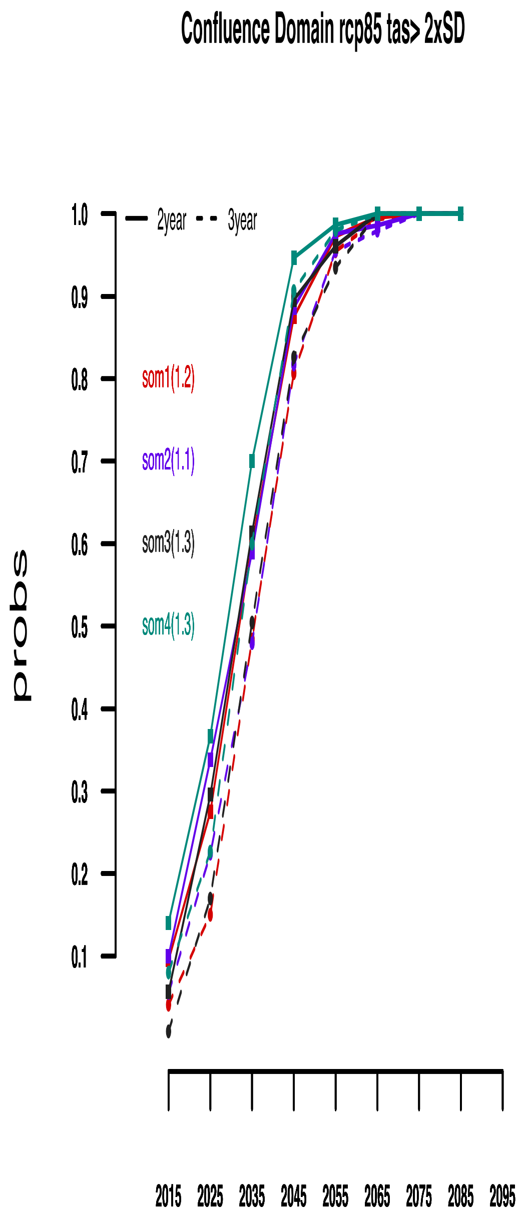
Figure CD15. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Confluence Domain under RCP8.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 Confluence Domain under RCP6.0 based on Figure CD15 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	1.50ºC/0.95	3.00ºC/0.95	4.25ºC/0.95
40	1→2→4	1.50ºC/0.95	3.00ºC/0.85	4.75ºC/0.80

Summary: A strong weighting towards future decreases in rainfall.

RCP8.5: temperature vs rainfall



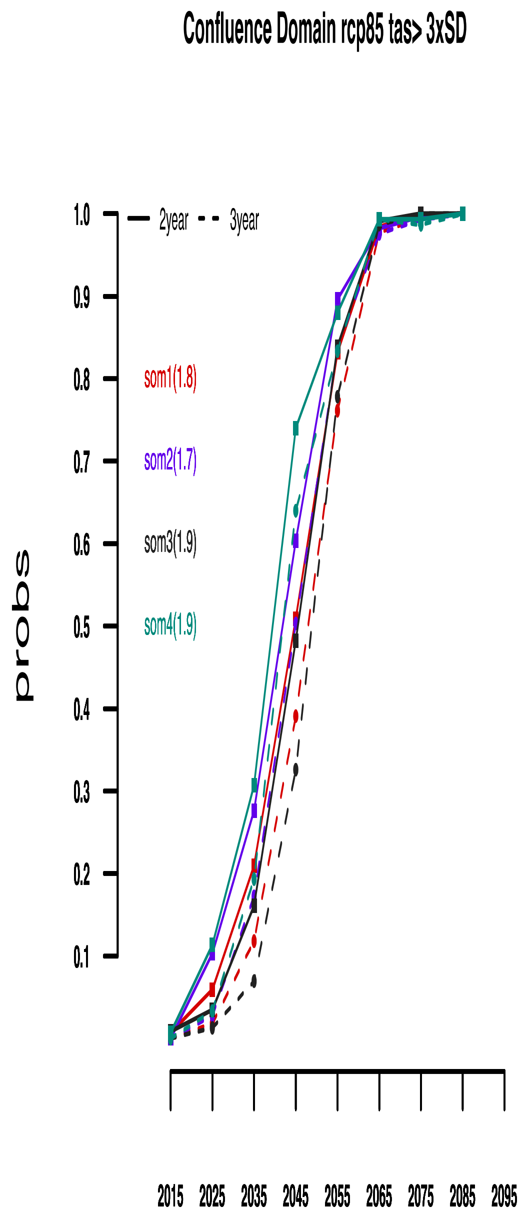


Figure CD17. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. 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

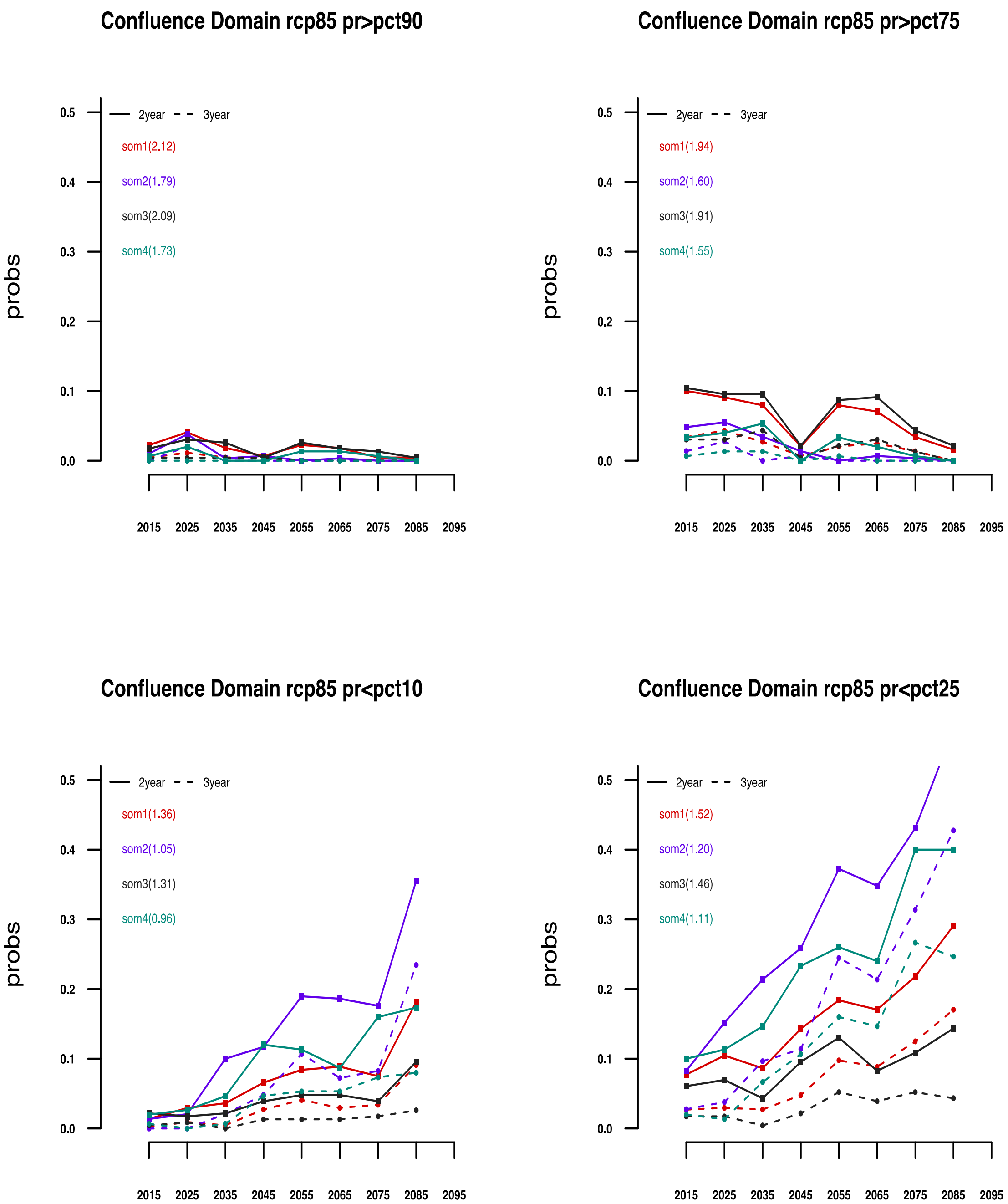


Figure CD18. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. 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.

RCP8.5: temperature vs rainfall less evaporation

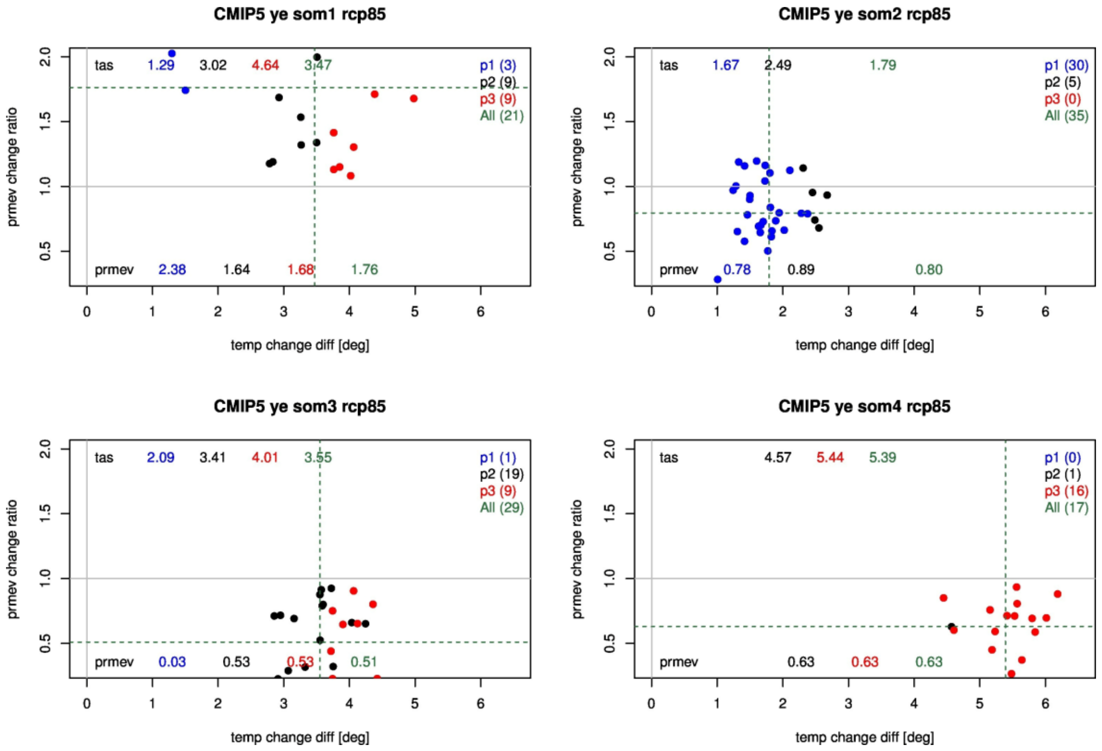


Figure CD19. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Confluence Domain under RCP8.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 CD4a. Scenarios for the year over the Confluence 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
75	2→3→4	1.50ºC/0.80	3.25ºC/0.60	5.00ºC/0.60
25	2→1	1.50ºC/0.80	2.75ºC/1.50	4.50ºC/1.70

Summary: With both suggested scenarios starting in som2 there is a substantial divergence later in the century. The scenario with highest likelihood heads towards substantially reduced water availability.

RCP8.5: temperature vs rainfall less evaporation

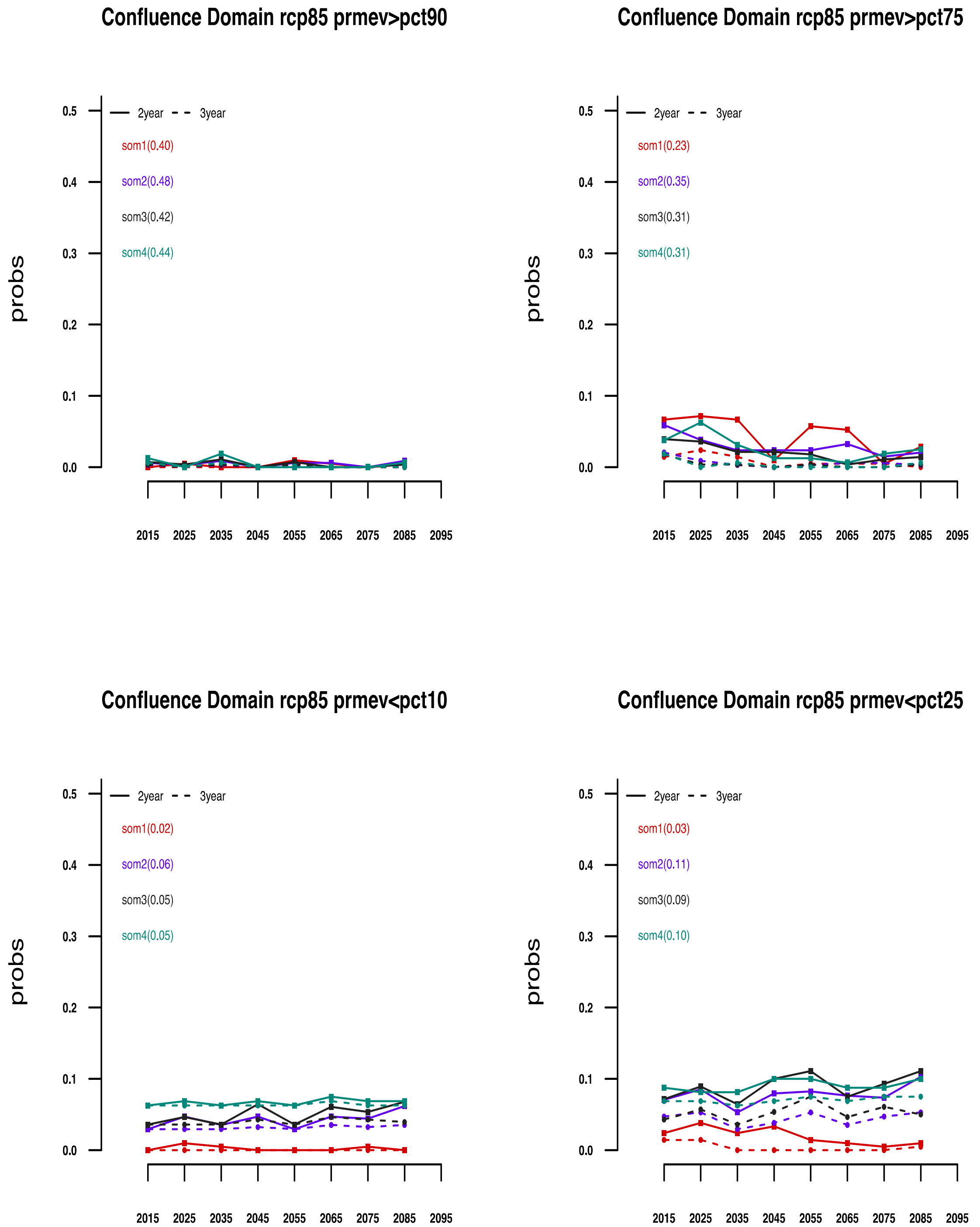


Figure CD20. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. 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.

RCP8.5: temperature vs rainfall less evaporation

Self-Organising Maps Results for the Namibia Domain

Introduction. Results are presented below for the analyses through self-organising maps (soms) for the Namibia 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; a limited number of rainfall less evaporation projections have been eliminated subjectively from the analyses where over-large changes in rainfall less evaporation results because of near-zero rainfall less evaporation values during the base period of 1986-2005.

Also provided towards the end of this document are results for the inter-annual variability (IAV) calculations, in all cases located immediately after the soms charts to which they refer. 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 1986-2005. 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.

Summary of results. There is a distinct difference in results between the temperature vs rainfall analyses and the temperature vs rainfall less evaporation analyses; in the former case there is strong weighting towards future decreased, but in the latter case there is some likelihood in increased rainfall less evaporation, although with higher likelihoods to a decrease.

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 are certainly weighted towards decreases in all suggested scenarios for all RCPs.

Temperatures in the recommended extreme scenarios increase in general with RCP; although extreme scenarios have been provided as an overview for RCP2.6, RCP4.5 and RCP6.0 the overall weighting towards reduced rainfall should be considered (and similarly for RCP8.5).

Likelihoods of annual temperatures over two- and three-year periods exceeding two and three standard deviations calculated across the base period of 1986-2005 increase, naturally, with RCP, but vary also according to individual soms. Under RCP8.5 successive two and three year periods are almost certain by the 2050's for two standard deviations and by the 2060's for three standard deviations. By contrast, under RCP2.6 none of the soms produces probabilities above about 80% for two standard deviations over two-year periods, whereas for three standard deviations probabilities peak for two soms at around 40%. For RCP4.5 100%

probabilities are reached only by the end of the century for two-year periods and for RCP6.0 by perhaps the 2080's over three-year periods for two standard deviations by the end of the century.

Likelihoods of annual rainfall totals outside the 90th percentiles over 2 and 3 years remain mainly below 5%, perhaps decreasing towards the end of the century and towards the higher RCPs. However for totals outside the 10th percentile there is a definite increase in likelihoods as the century progresses, in one som under RCP8.5 reaching almost 40% for two-year periods; there seems also to be an increase in likelihoods with higher RCPs. There is a similar picture of future drying based on likelihoods outside the 25th and 75th percentiles, with values for the latter remaining below 10%, except perhaps for RCP2.6, and perhaps declining in time, while there is an upward trend for the former (with the possible exception of RCP2.6) reaching over 50% for twoRCP6.0 and RCP8.5 soms over two years.

Temperature against rainfall less evaporation. The picture is a little more complex for rainfall less evaporation in comparison to rainfall alone, with greater likelihoods of increased rainfall less evaporation.

Temperatures in the suggested extreme scenarios increase in general with RCP; for rainfall less evaporation extremes there is a high likelihood that the increases may apply than for the case from the rainfall only analyses discussed above.

Distributions of rainfall less evaporation are such that both the 10th and 25th percentiles are largely populated with zeros or negative values, resulting in meaningless probabilities for the projections. Likelihoods for both two- and three-year periods for above the 75th and 90th percentiles are below 10% and may decline towards the end of the century.

Conclusions. In section 3 of the main report it was noted that the Namibia Domain sits at a location where, proportionately, future rainfall decreases are close to the maximum across southern Africa according to the ensemble means. The same is not necessarily true for changes in rainfall less evaporation for which there are increases in some of the ensemble means. Temperature changes, again in the ensemble means, are broadly similar to those in the Lesotho and Vaal Domains, and less perhaps than those in the Confluence Domain; it may be this adjustment in projected temperature changes that accounts for the differences between the temperature vs rainfall and the temperature vs rainfall less evaporation results.

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. It suggests approximately similar prospects of increased and decreased water availability in both analyses but with slightly higher likelihood for an increase in the temperature vs rainfall assessment and for a decrease in the temperature vs rainfall less evaporation assessment. These differences in likelihoods 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. Frequencies of periods of relatively heavy and relative light rainfall, as assessed through the IAV analyses, indicate that the future climate will, on the whole, move towards drier conditions. Limited conclusions may be drawn from the rainfall less evaporation IAV analyses other than there appear to be future decreases in the heavier rainfall events.

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

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
60	1.00ºC/0.95	1.75ºC/0.95	2.25ºC/0.90
40	1.25ºC/0.80	2.00ºC/0.80	2.50ºC/0.80

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	1.25ºC/0.75	1.50ºC/0.75	2.25ºC/0.75

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
60	1.00ºC/0.90	1.75ºC/0.85	2.25ºC/0.80
40	1.00ºC/1.20	1.50ºC/1.20	1.75ºC/1.20

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	1.50ºC/1.40	2.50ºC/1.40
Decreased	1.25ºC/0.70	1.50ºC/0.60	2.00ºC/0.60

Recommended Scenarios for the Namibia Domain based on RCP8.5

Recommended scenarios based on temperature against rainfall analyses

%	2040	2065	2080
90	1.50ºC/0.90	3.00ºC/0.85	4.25ºC/0.85
10	1.50ºC/0.90	3.00ºC/0.70	5.00ºC/0.65

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

	2040	2065	2080
Increased	1.50ºC/1.10	2.00ºC/1.05	3.50ºC/1.10
Decreased	1.50ºC/0.80	3.00ºC/0.70	4.50ºC/0.70

Recommended scenarios based on temperature against rainfall less evaporation analyses

%	2040	2065	2080
60	1.75ºC/0.90	3.25ºC/0.85	4.50ºC/0.85
40	1.50ºC/1.60	2.75ºC/1.50	4.25ºC/1.60

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

	2040	2065	2080
Increased	1.50ºC/1.70	2.75ºC/1.70	4.25ºC/1.80
Decreased	1.75ºC/0.60	3.25ºC/0.50	5.00ºC/0.50

RCP8.5: temperature vs rainfall less evaporation

Scenarios from each RCP for the Namibia 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

	%		2040	2065	2080		%		2040	2065	2080
1	35	2	1.00ºC/0.95	1.00ºC/0.95	1.00ºC/0.90		40	1	1.00ºC/1.05	1.00ºC/1.15	1.00ºC/1.10
2	30	1	0.75ºC/1.00	1.00ºC/1.00	0.75ºC/1.00		35	3→4	1.25ºC/0.85	1.50ºC/0.85	1.50ºC/0.90
3	20	3	1.25ºC/0.80	1.50ºC/0.80	1.50ºC/0.80		25	2	1.50ºC/0.75	1.50ºC/0.70	1.25ºC/0.70
4	15	4	1.50ºC/0.90	1.75ºC/0.90	2.00ºC/0.90						

Summary: The weoht in both TR and TRLE is towards a decrease in water availability. Line 2 in TR suggests no possible increase in rainfall although Line 1 in TRLE indicates a possible increase in water availability.

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/1.05	1.00ºC/1.05	1.00ºC/1.10		1.00ºC/1.00	1.25ºC/1.10	1.25ºC/1.05
Decreased	1.25ºC/0.80	1.75ºC/0.80	2.25ºC/0.80		1.25ºC/0.75	1.50ºC/0.60	1.50ºC/0.60

RCP4.5

	%		2040	2065	2080		%		2040	2065	2080
1	60	1→3	1.25ºC/1.00	2.00ºC/0.95	2.25ºC/0.95		50	1→3	1.25ºC/1.50	1.75ºC/1.20	1.75ºC/1.20
2	40	2→4	1.25ºC/0.85	2.00ºC/0.80	2.50ºC/0.75		50	2→4	1.25ºC/0.85	2.00ºC/0.80	2.50ºC/0.80

Summary: In an equivalent outcome to that for RCP2.6 the suggested scenarios in TR both indicate future rainfall decreases. Nevertheless the scenario in Line 1 of TRLE suggests a possible increase 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

RCP8.5: temperature vs rainfall less evaporation

	2040	2065	2080		2040	2065	2080
Increased	1.25ºC/1.00	2.25ºC/1.10	2.50ºC/1.05		1.00ºC/1.50	2.25ºC/1.50	2.50ºC/1.50
Decreased	1.00ºC/0.80	1.75ºC/0.80	2.50ºC/0.75		1.25ºC/0.60	2.00ºC/0.60	2.50ºC/0.50

RCP6.0

	%		2040	2065	2080		%		2040	2065	2080
1	70	1→3	1.00ºC/0.95	2.75ºC/0.95	2.25ºC/0.95		50	1→3	1.00ºC/0.95	2.00ºC/0.80	2.25ºC/0.85
2	30	2→4	1.00ºC/0.80	2.00ºC/0.80	3.00ºC/0.75		30	1→2	1.00ºC/0.95	1.75ºC/1.30	2.50ºC/1.40
3							20	1→4	1.00ºC/0.95	2.75ºC/0.75	3.25ºC/0.85

Summary: There seems to be a pattern for the Namibia Domain in which the suggested rainfall scenarios in TR all indicate decreases whereas one possible scenario in TRLE indicates an increase in water availability, as here.

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/1.00	1.75ºC/1.05	1.75ºC/1.05		1.25ºC/1.40	1.50ºC/1.50	2.50ºC/1.50
Decreased	1.00ºC/0.85	1.75ºC/0.80	3.00ºC/0.75		1.25ºC/0.70	2.00ºC/0.60	3.00ºC/0.60

RCP8.5

	%		2040	2065	2080		%		2040	2065	2080
1	90	1→3	1.50ºC/0.90	3.00ºC/0.85	4.25ºC/0.85		60	2→3→4	1.75ºC/0.90	3.25ºC/0.85	4.50ºC/0.85
2	10	1→2→4	1.50ºC/0.90	3.00ºC/0.70	5.00ºC/0.65		40	1	1.50ºC/1.60	2.75ºC/1.50	4.25ºC/1.60

Summary: The pattern of decreases throughout TR but with one scenario suggesting an increase in water availability continues to RCP8.5.

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	1.50ºC/1.10	2.00ºC/1.05	3.50ºC/1.10		1.50ºC/1.70	2.75ºC/1.70	4.25ºC/1.80
Decreased	1.50ºC/0.80	3.00ºC/0.70	4.50ºC/0.70		1.75ºC/0.60	3.25ºC/0.50	5.00ºC/0.50

RCP2.6; temperature vs rainfall

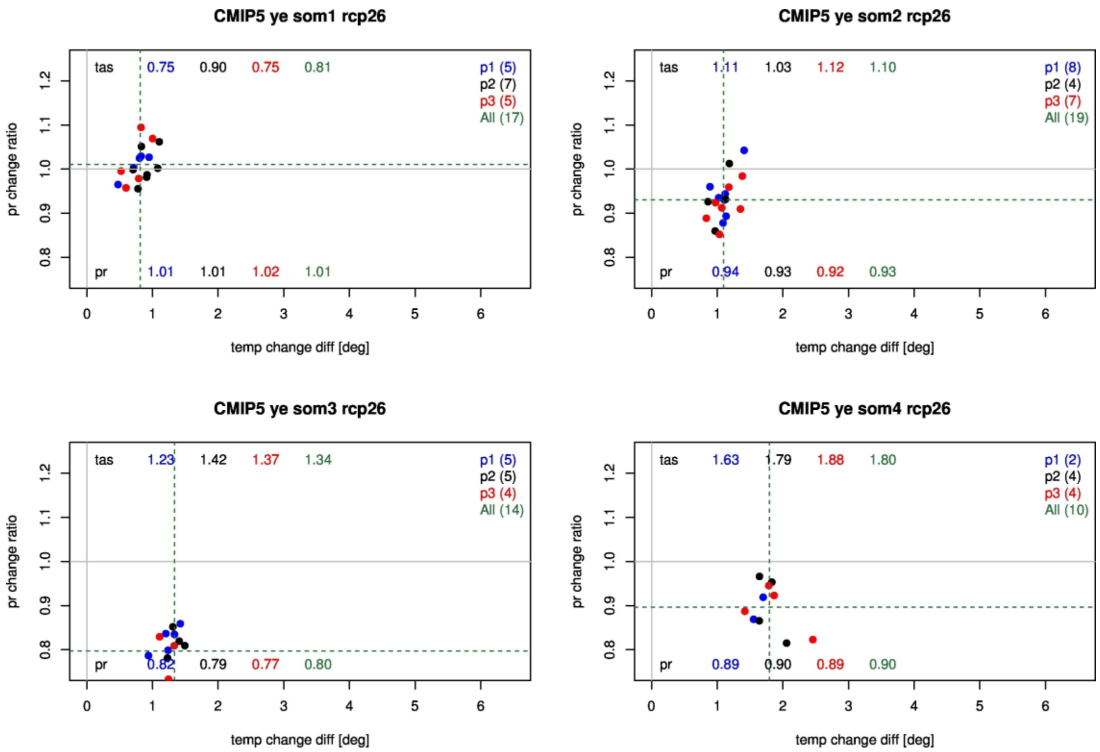


Figure ND25. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Namibia Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 ND1a. Scenarios for the year over the Namibia Domain under RCP2.6 based on Figure ND1 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	2	1.00ºC/0.95	1.00ºC/0.95	1.00ºC/0.90
30	1	0.75ºC/1.00	1.00ºC/1.00	0.75ºC/1.00
20	3	1.25ºC/0.80	1.50ºC/0.80	1.50ºC/0.80
15	4	1.50ºC/0.90	1.75ºC/0.90	2.00ºC/0.90

Summary: The overall weighting of the recommended scenarios is certainly towards decreased future rainfall, with only one, second highest in terms of likelihoods, suggesting maintenance of current levels.

RCP2.6; temperature vs rainfall

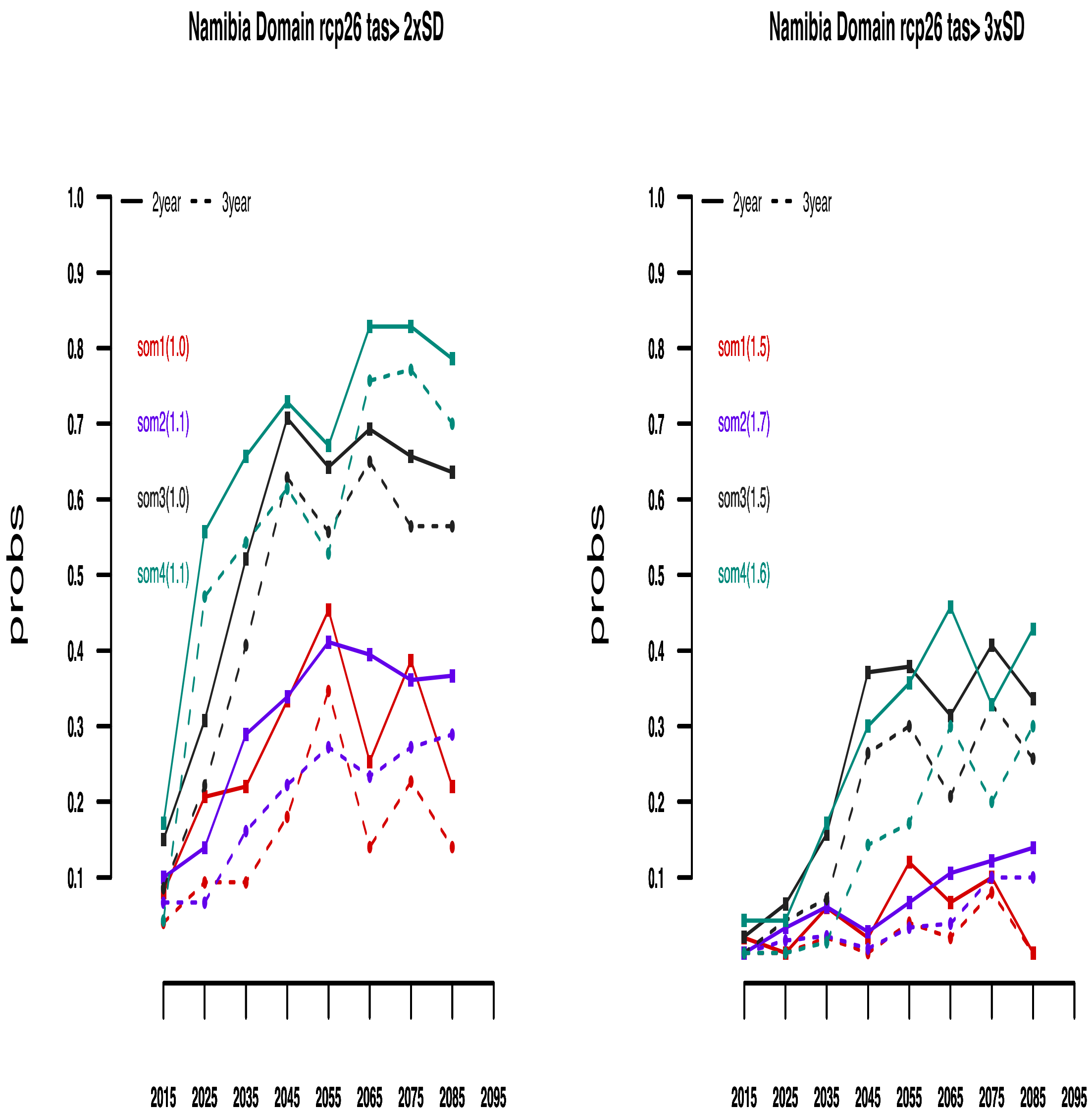


Figure ND26. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND1 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

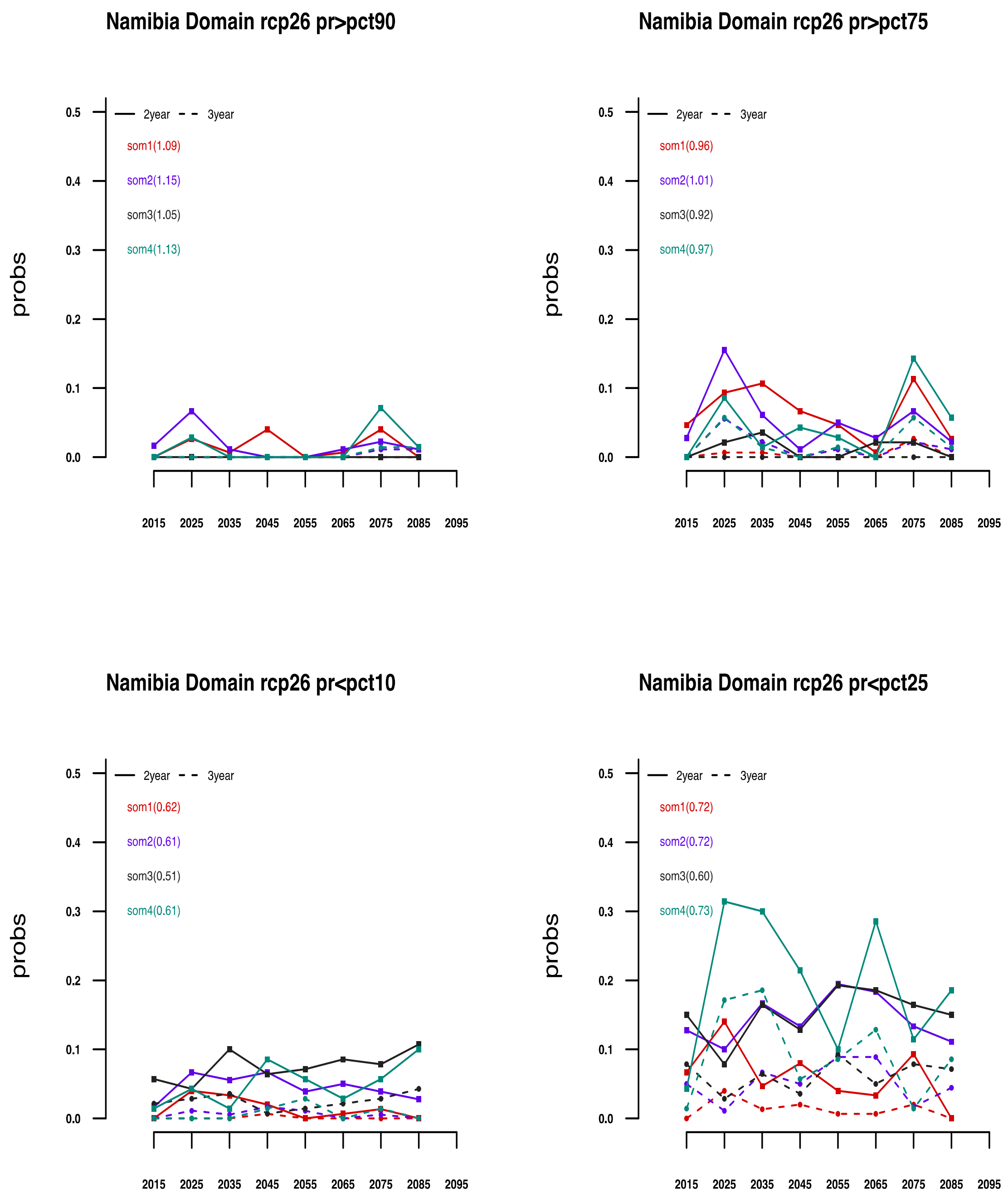


Figure ND27. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND1 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

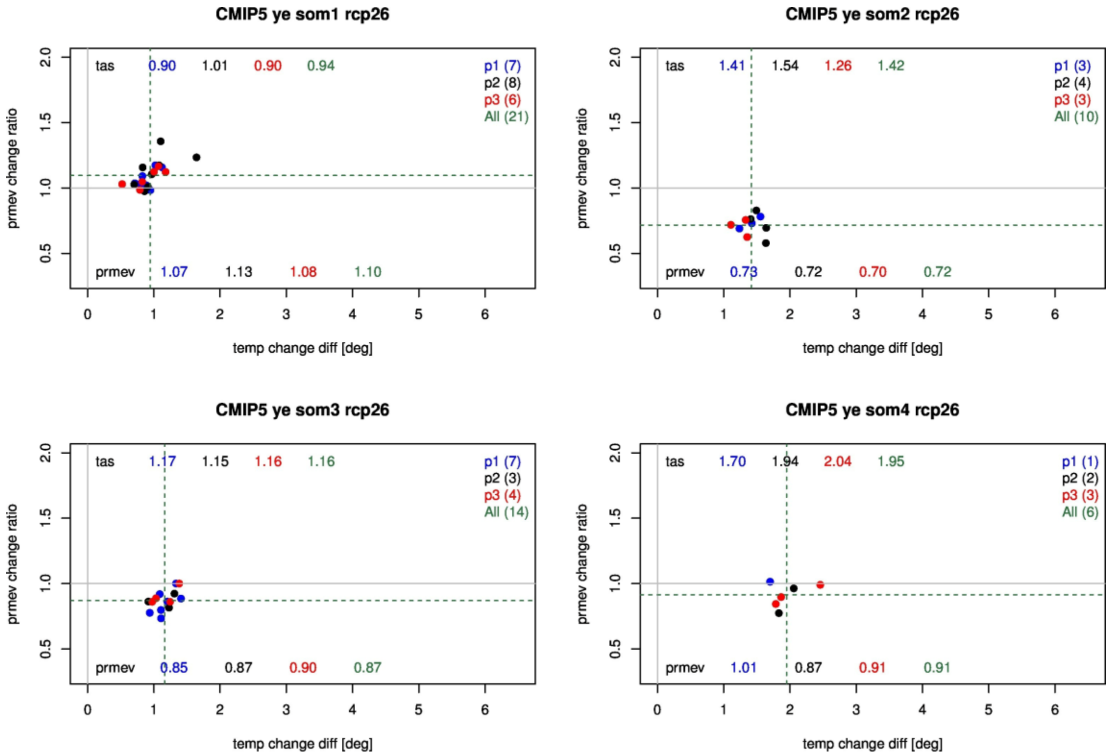


Figure ND4. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Namibia Domain under RCP2.6; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 17 projections in CMIP5 for RCP2.6.

Table ND2a. Scenarios for the year over the Namibia Domain under RCP2.6 based on Figure ND4 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 less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
40	1	1.00ºC/1.05	1.00ºC/1.15	1.00ºC/1.10
35	3→4	1.25ºC/0.85	1.50ºC/0.85	1.50ºC/0.90
25	2	1.50ºC/0.75	1.50ºC/0.70	1.25ºC/0.70

Summary: A clear weighting towards future reductions in water availability even though the suggested scenario with the highest likelihood is for an increase.

RCP2.6; temperature vs rainfall less evaporation

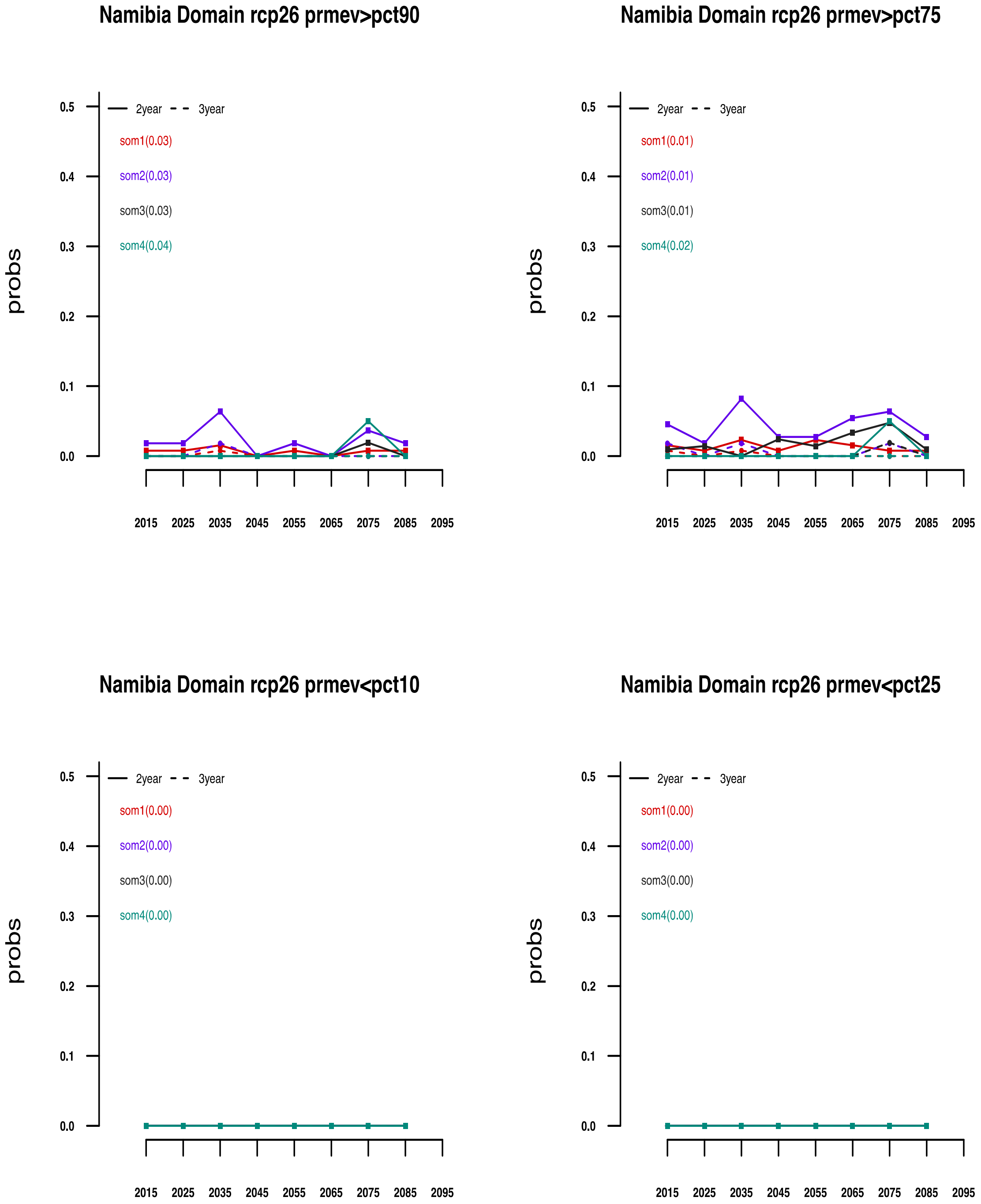


Figure ND5. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND4 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

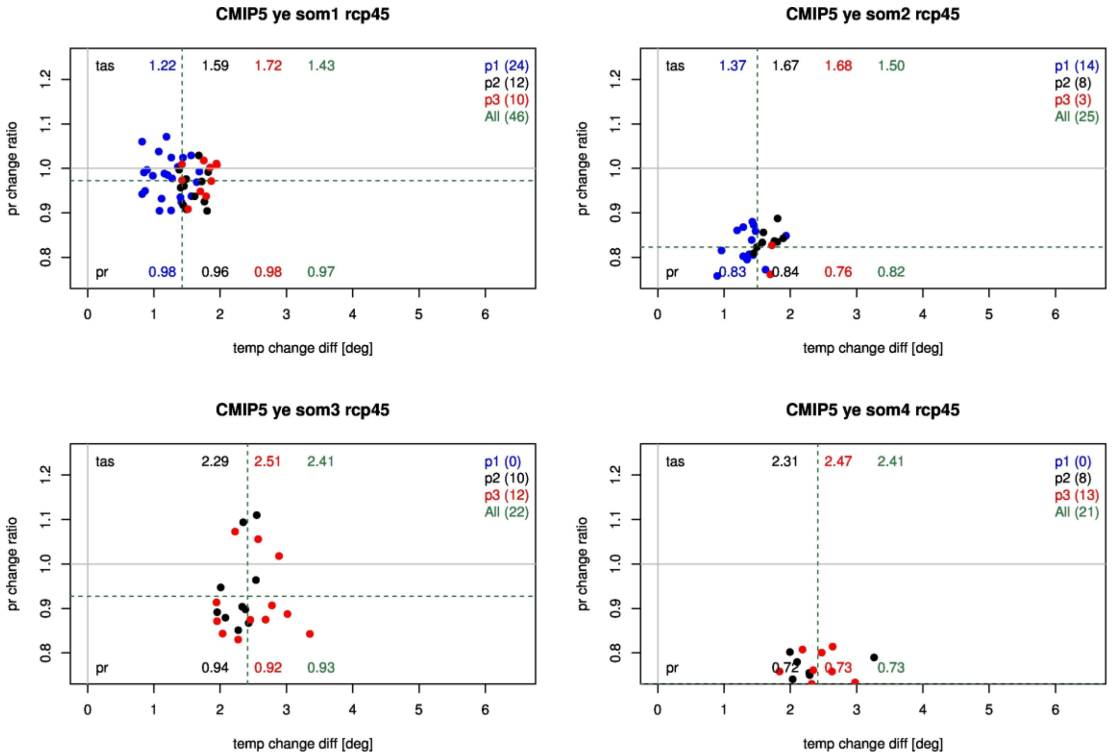


Figure ND6. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Namibia Domain under RCP4.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 ND3a. Scenarios for the year over the Namibia Domain under RCP4.5 based on Figure ND6 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	1.25ºC/1.00	2.00ºC/0.95	2.25ºC/0.95
40	2→4	1.25ºC/0.85	2.00ºC/0.80	2.50ºC/0.75

Summary: A rapid reduction in water availability is suggested in the scenario with lowest likelihood. The other scenario still suggests, in effect, a decrease.

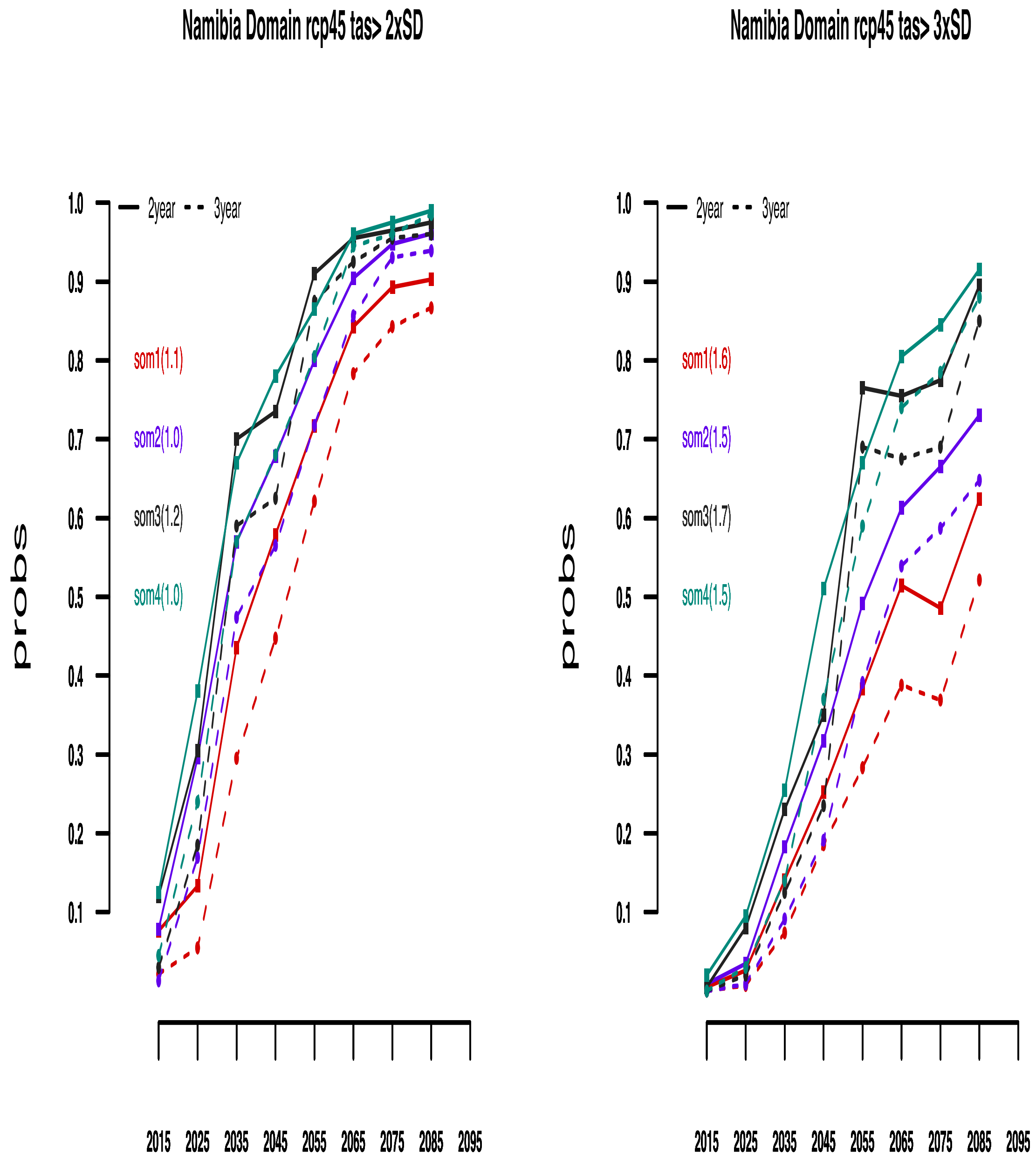


Figure ND7. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND6 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

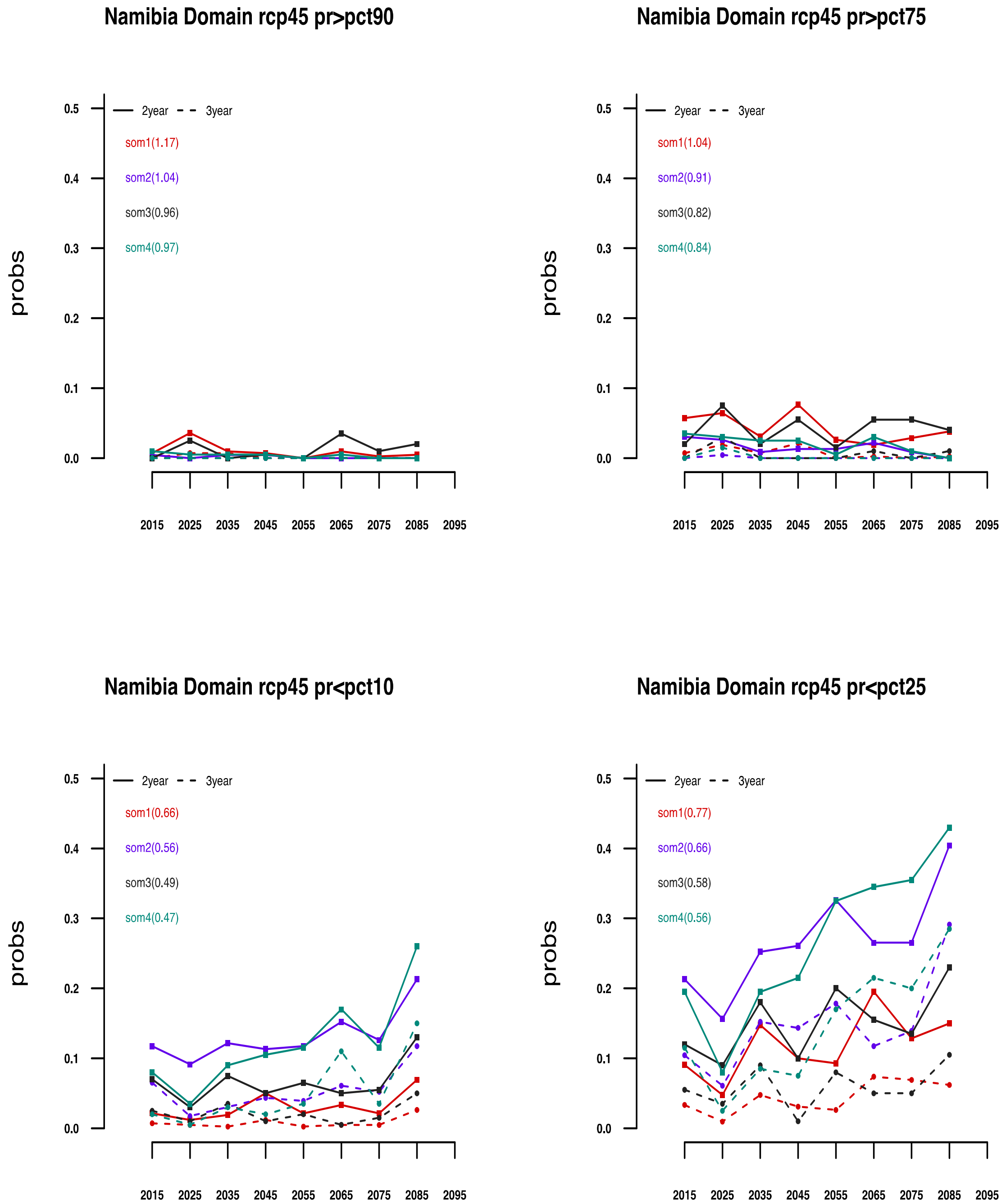


Figure ND8. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND6 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

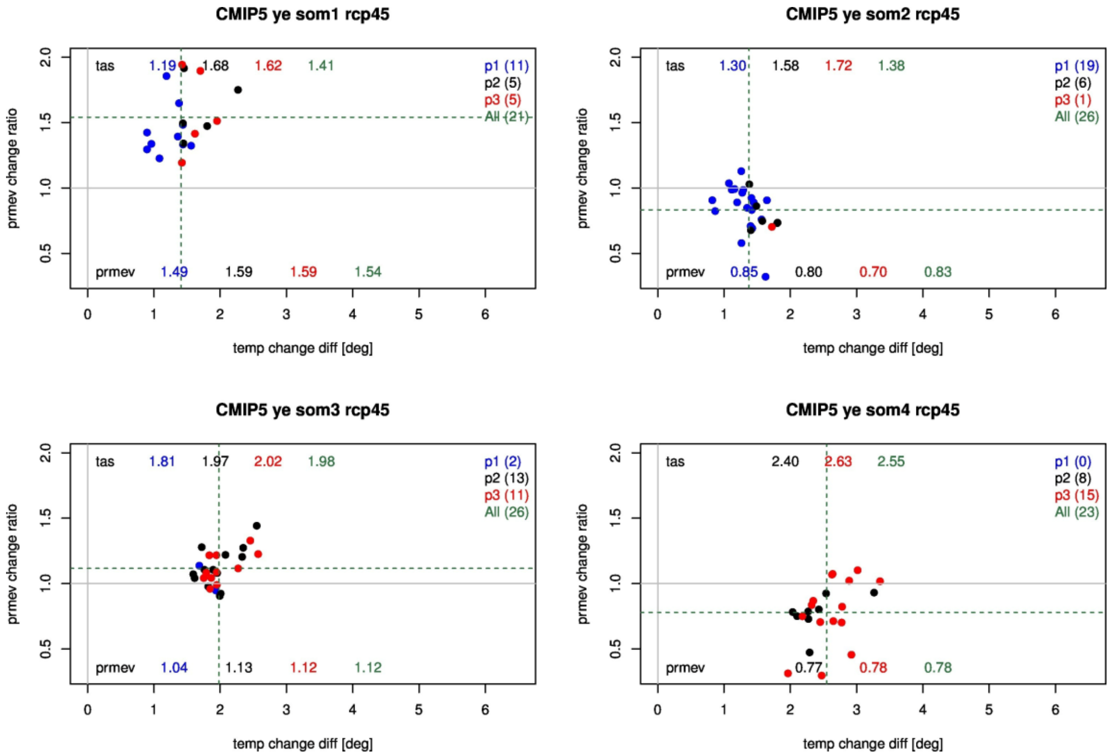


Figure ND9. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Namibia Domain under RCP4.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 RCP4.5.

Table ND4a. Scenarios for the year over the Namibia Domain under RCP4.5 based on Figure ND9 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 less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
50	1→3	1.25ºC/1.50	1.75ºC/1.20	1.75ºC/1.20
50	2→4	1.25ºC/0.85	2.00ºC/0.80	2.50ºC/0.80

Summary: Two suggested scenarios with similar likelihoods but opposite directions for changes in water availability. It should be noted, however, that the wetter scenario does begin with a rapid increase in prmev, tempered later, presumably an indicator that some projections with substantial ratios of prmev are still present in the set.

RCP4.5; temperature vs rainfall less evaporation

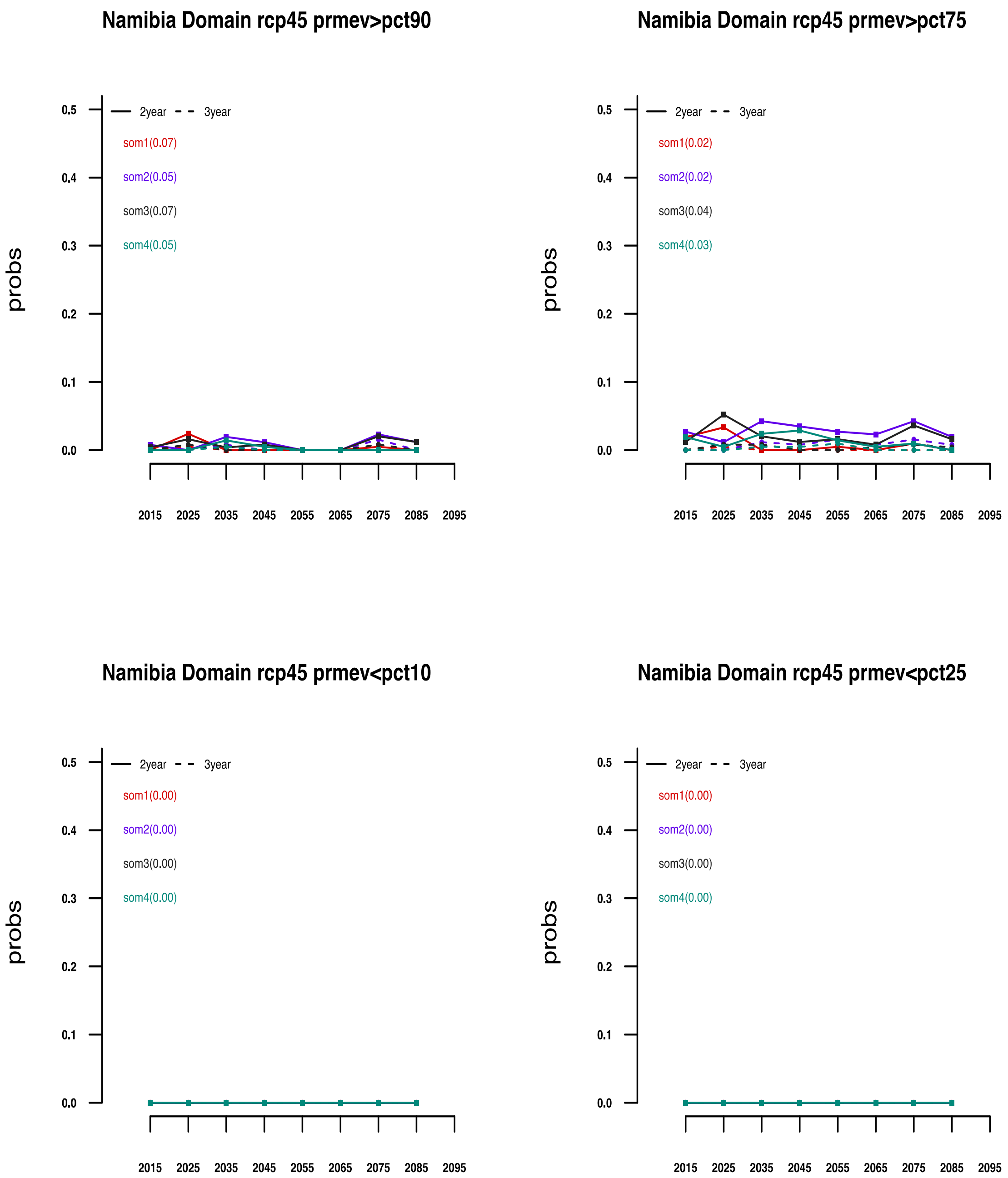


Figure ND10. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND9 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

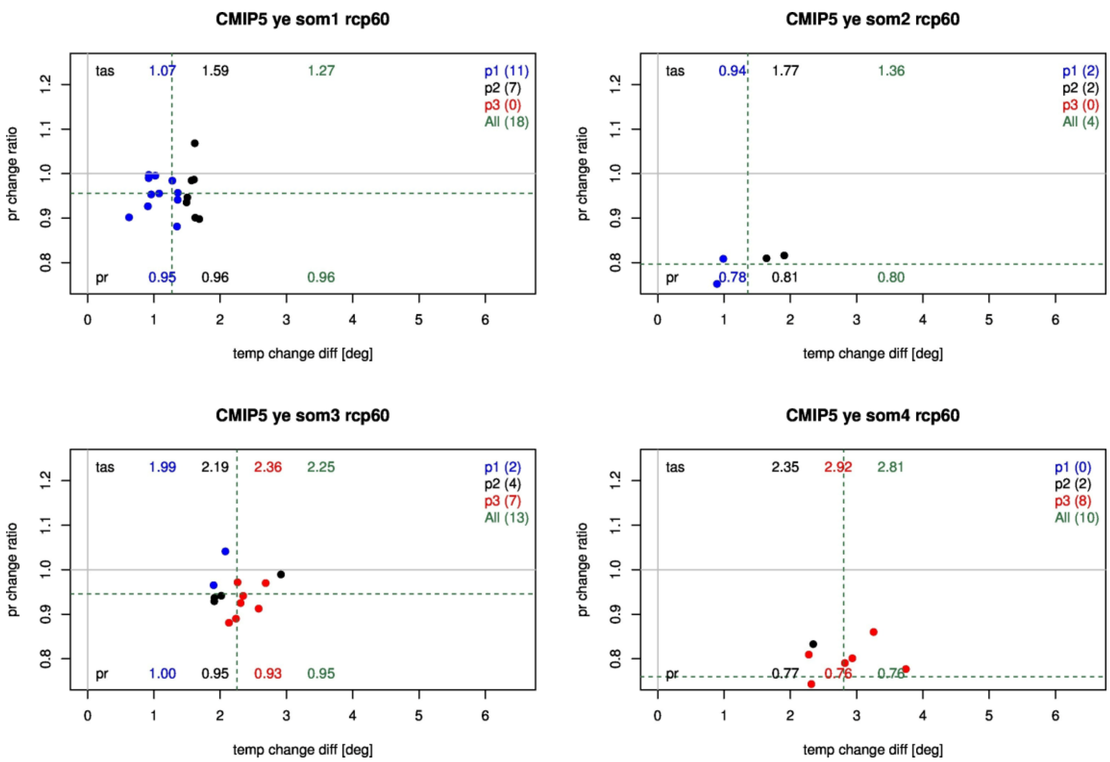


Figure ND11. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Namibia Domain under RCP6.0 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 ND5a. Scenarios for the year over the Namibia Domain under RCP6.0 based on Figure ND11 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
70	1→3	1.00ºC/0.95	2.75ºC/0.95	2.25ºC/0.95
30	2→4	1.00ºC/0.80	2.00ºC/0.80	3.00ºC/0.75

Summary: Rainfall decreases in both suggested scenarios.

RCP6.0; temperature vs rainfall

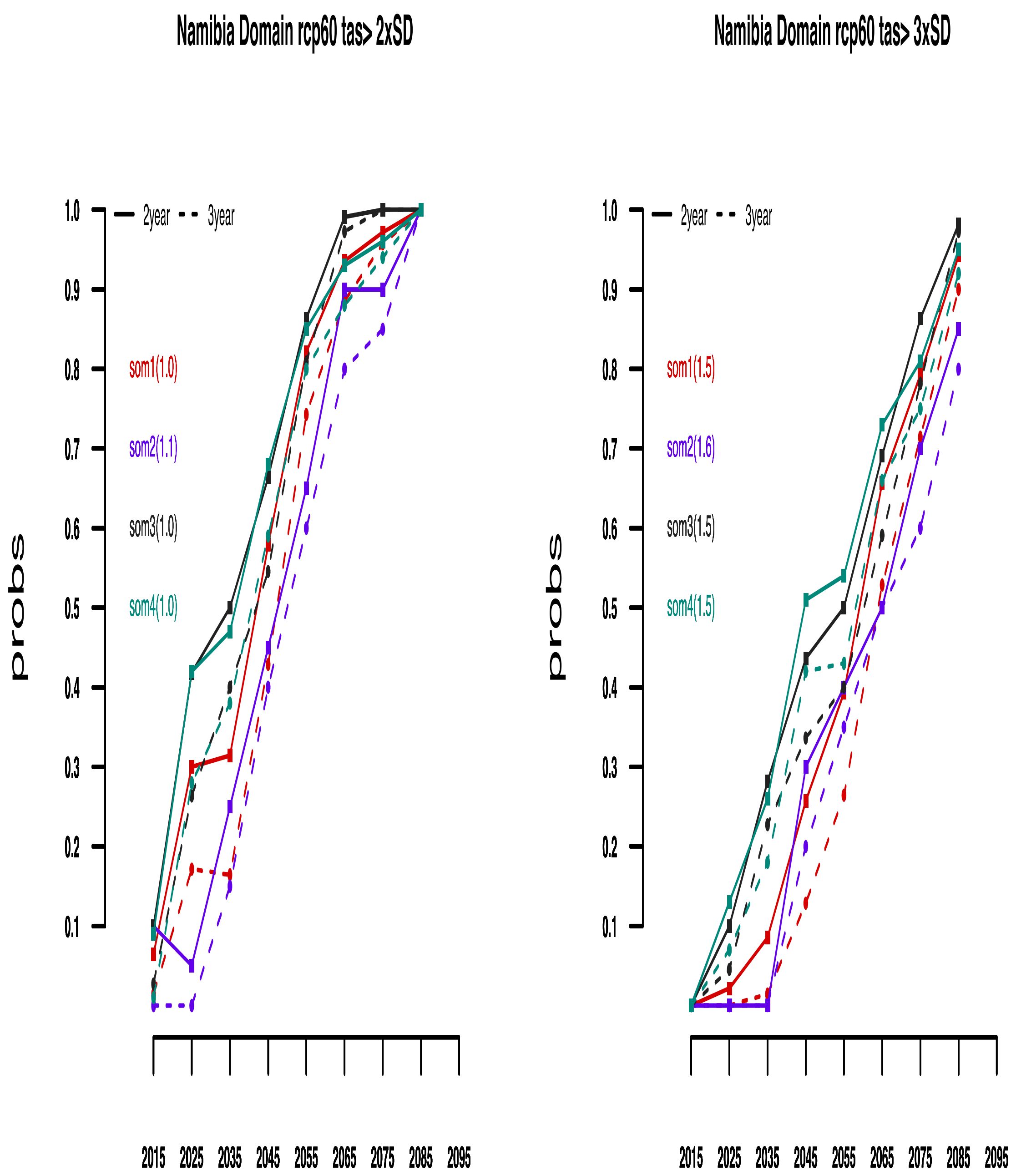


Figure ND12. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND11 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

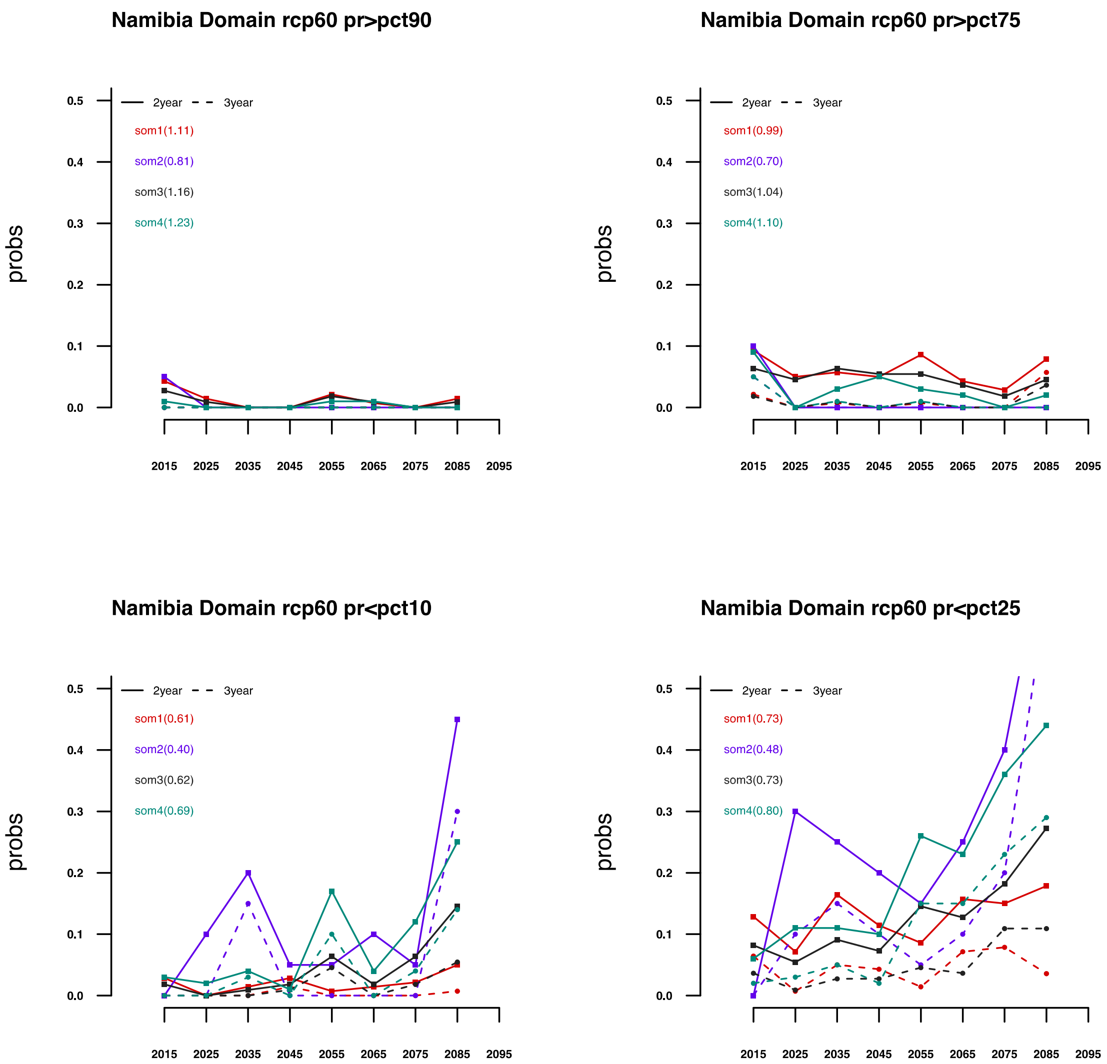


Figure ND13. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND11 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

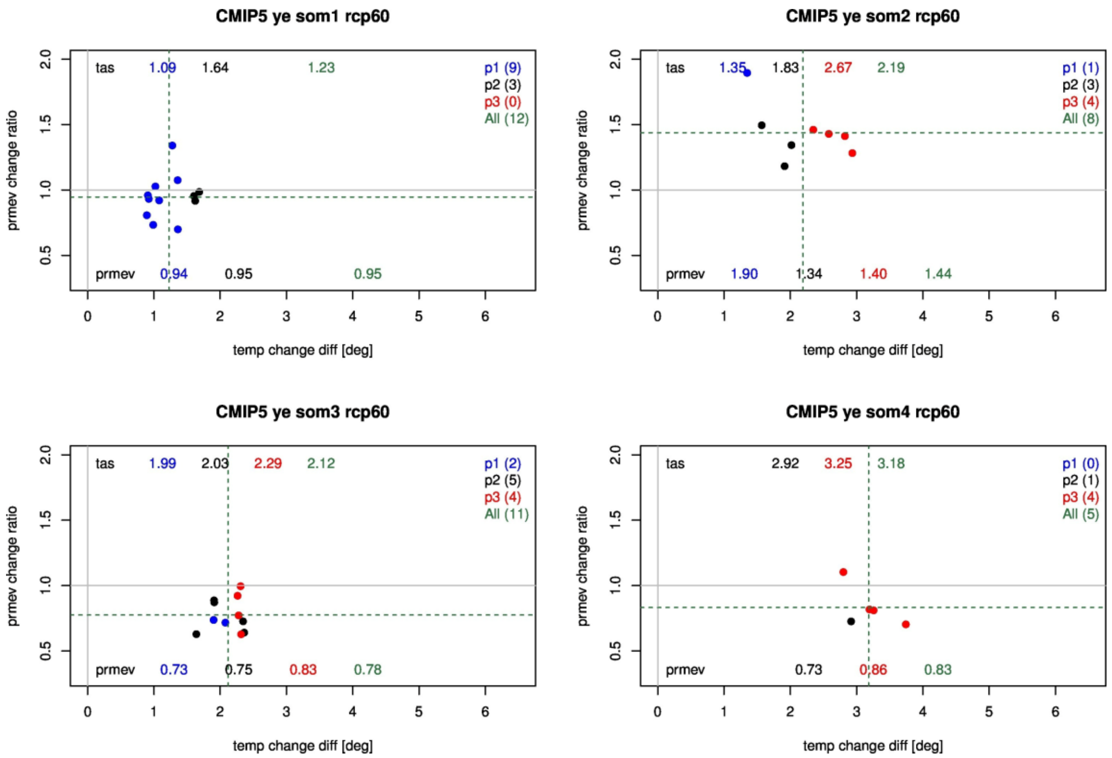


Figure ND12. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Namibia Domain under RCP6.0; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 ND3a. Scenarios for the year over the Namibia Domain under RCP6.0 based on Figure ND12 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 less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
50	1→3	1.00ºC/0.95	2.00ºC/0.80	2.25ºC/0.85
30	1→2	1.00ºC/0.95	1.75ºC/1.30	2.50ºC/1.40
20	1→4	1.00ºC/0.95	2.75ºC/0.75	3.25ºC/0.85

Summary: There is a possibility of an increase in water availability, with a suggested likelihood of about 30%. Otherwise the scenarios suggest a substantial decrease.

RCP6.0; temperature vs rainfall less evaporation

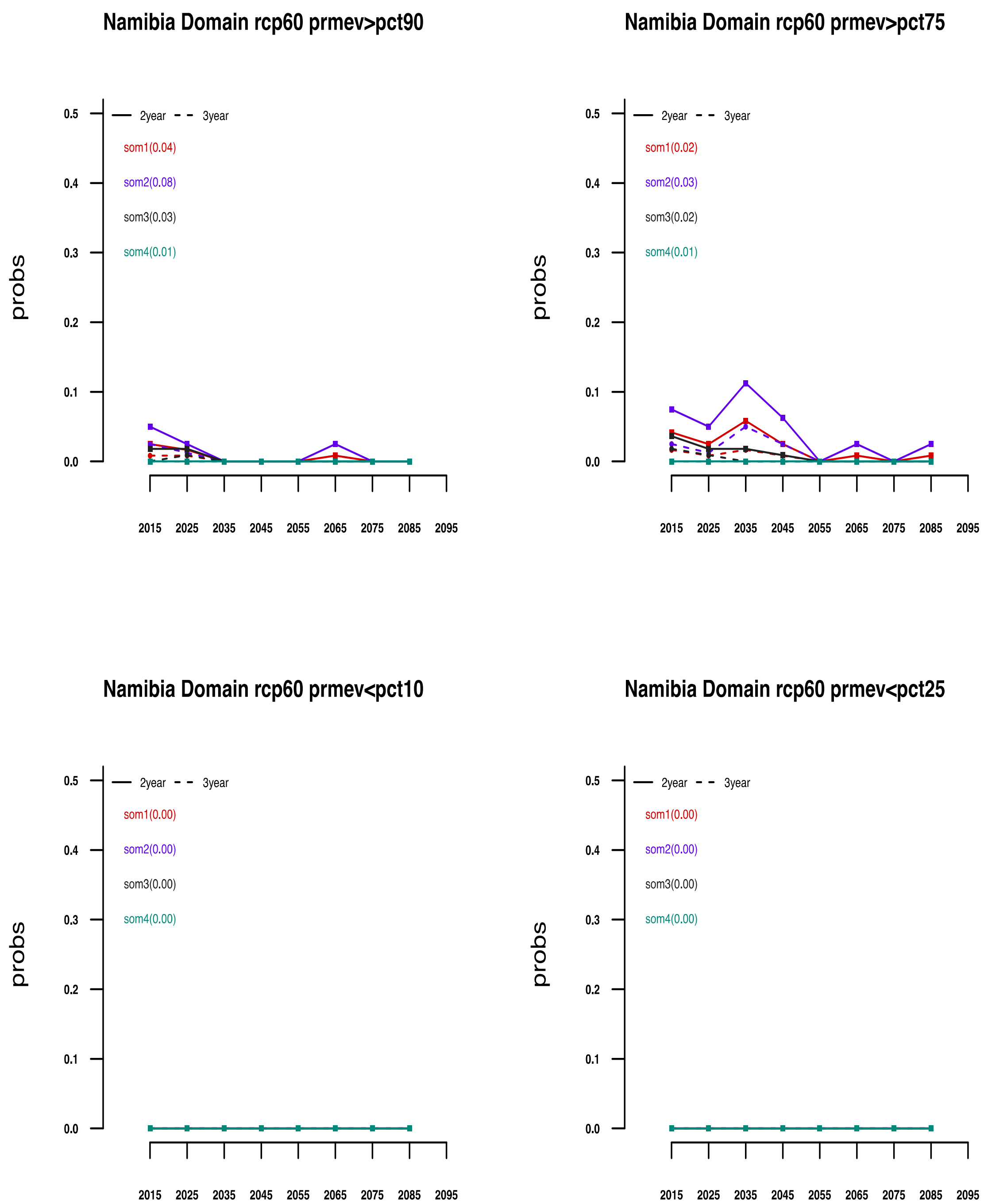


Figure ND128. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND14 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

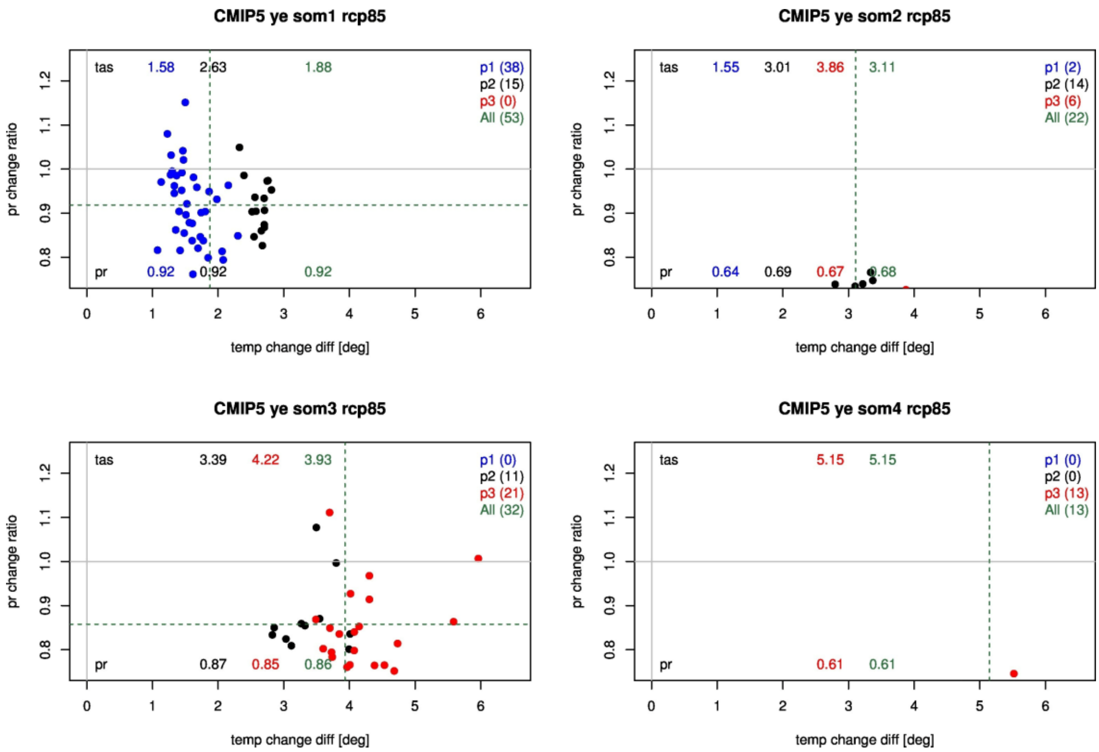


Figure ND7. Self-organising maps charts for rainfall (along vertical axis) against temperature (along horizontal axis) for the year over the Namibia Domain under RCP8.5 charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall vs temperature projection relative to the base period of 1986-2005 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 ND7a. Scenarios for the year over the Namibia Domain under RCP6.0 based on Figure ND7 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
90	1→3	1.50ºC/0.90	3.00ºC/0.85	4.25ºC/0.85
10	1→2→4	1.50ºC/0.90	3.00ºC/0.70	5.00ºC/0.65

Summary: These projections provide little hope for any increase, or even any maintenance, in current rainfall levels in the future. The first suggested scenario is dominant in terms of likelihoods, with even more severe reductions in the second. This appears to be an unusual soms analysis with effectively most projections within a single scenario.

RCP8.5; temperature vs rainfall

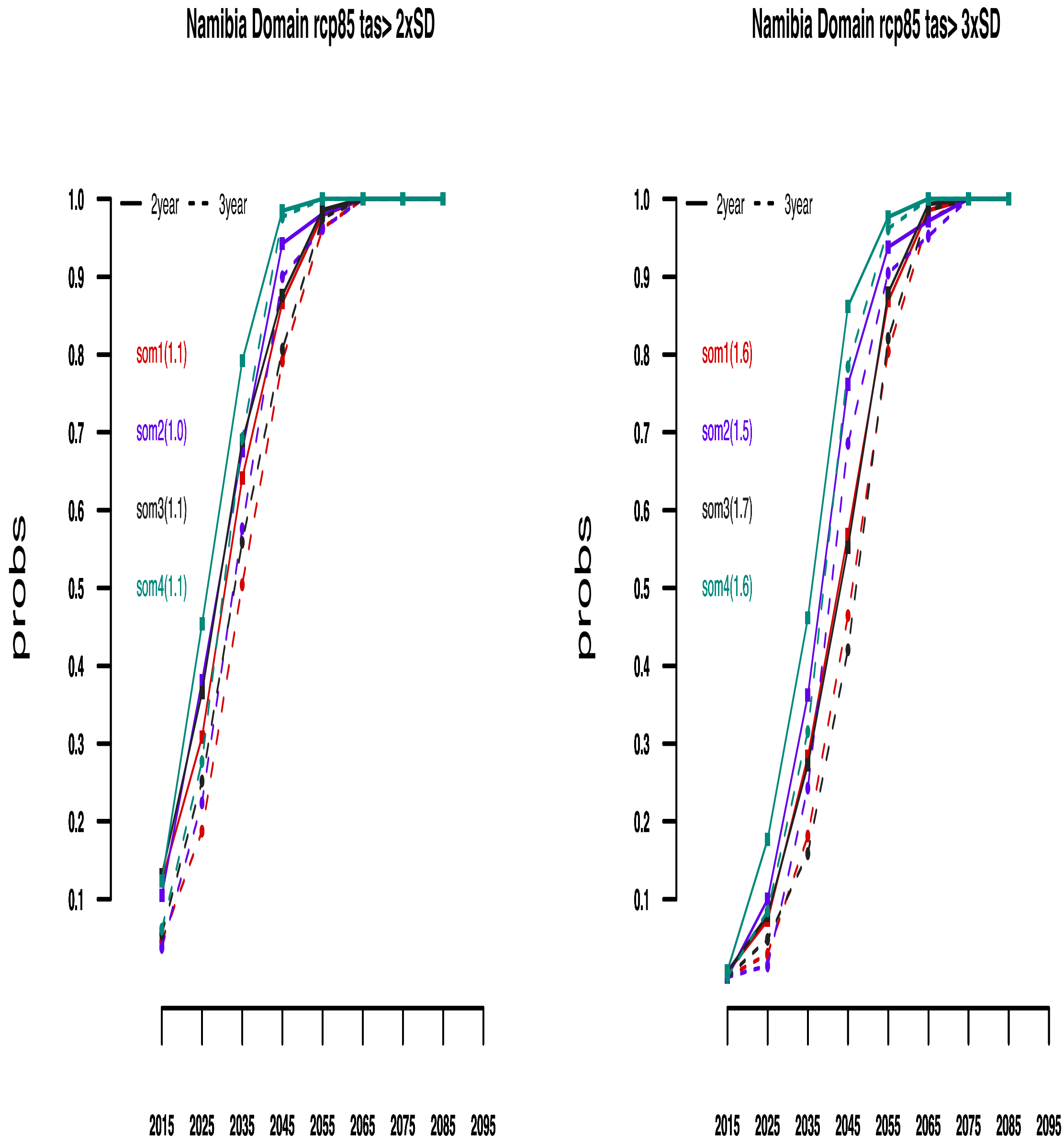


Figure ND17. Decadal probabilities that future annual temperatures will exceed 2 and 3 standard deviations (left chart and right chart respectively) over successive two- and three-year periods based on the standard deviations of annual temperature calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND16 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

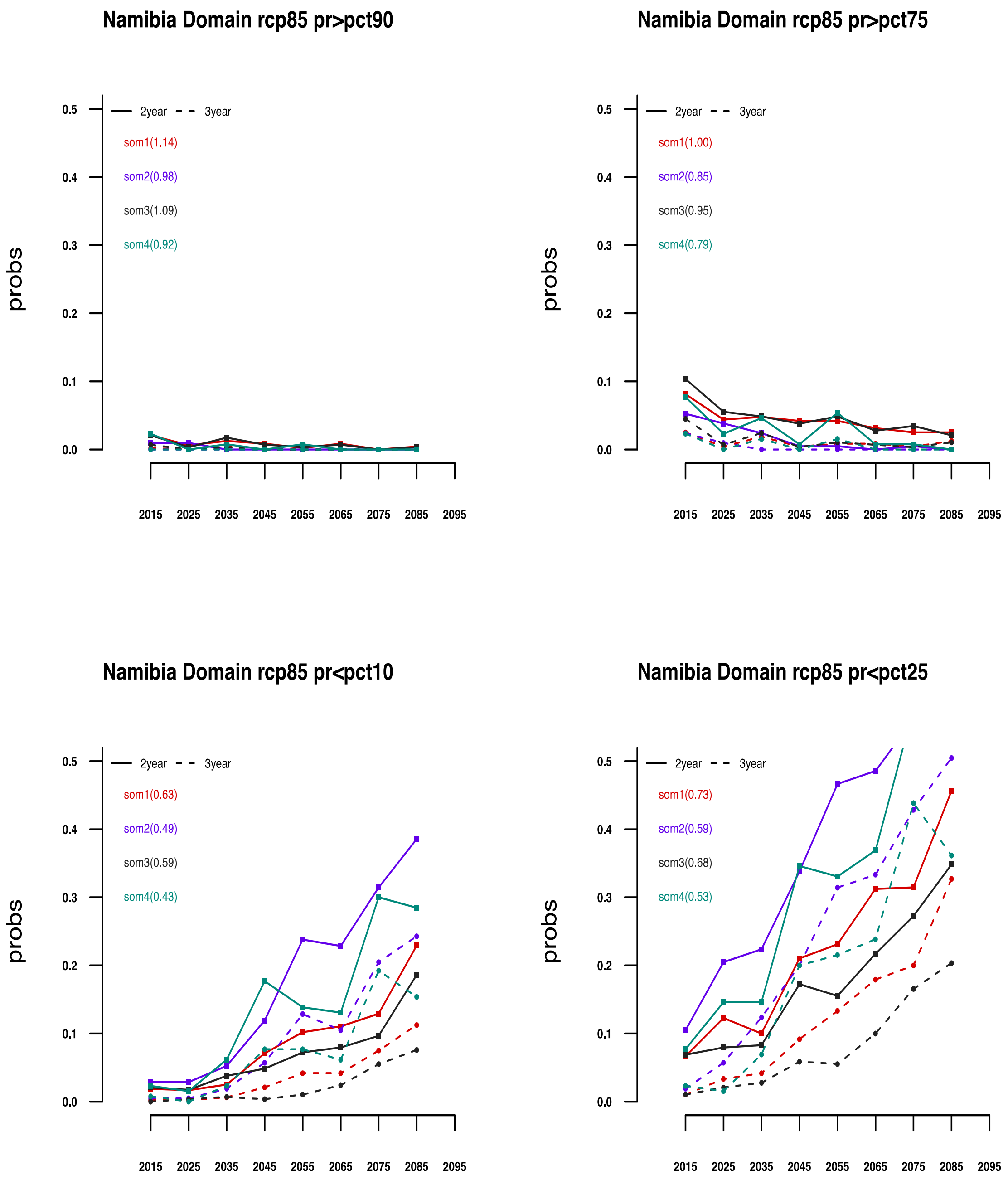


Figure ND18. Decadal probabilities that future annual rainfall totals will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for total annual rainfall calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND16 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 less evaporation

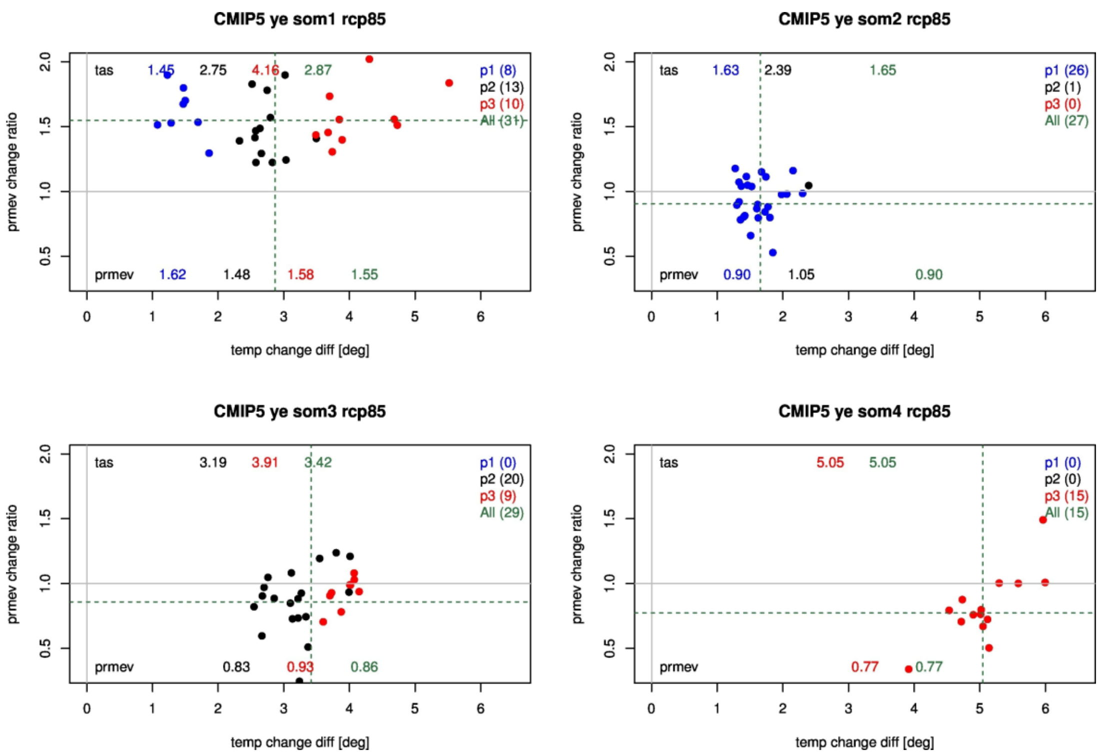


Figure ND19. Self-organising maps charts for rainfall less evaporation (along vertical axis) against temperature (along horizontal axis) for the year over the Namibia Domain under RCP8.5; charts are numbered entirely arbitrarily 1 (top left), 2 (top right), 3 (bottom left) and 4 (bottom right). Each point represents a rainfall less evaporation (prmev)/temperature projection relative to the base period of 1986-2005 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 ND8a. Scenarios for the year over the Namibia Domain under RCP8.5 based on Figure ND19 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 less evaporation changes to 5% - values above 1.00 represent increases, below 1.00 decreases.

%		2040	2065	2080
60	2→3→4	1.75ºC/0.90	3.25ºC/0.85	4.50ºC/0.85
40	1	1.50ºC/1.60	2.75ºC/1.50	4.25ºC/1.60

Summary: The suggested scenario with lowest likelihood, if it is to be accepted, indicates a rapid and maintained increase in water availability.

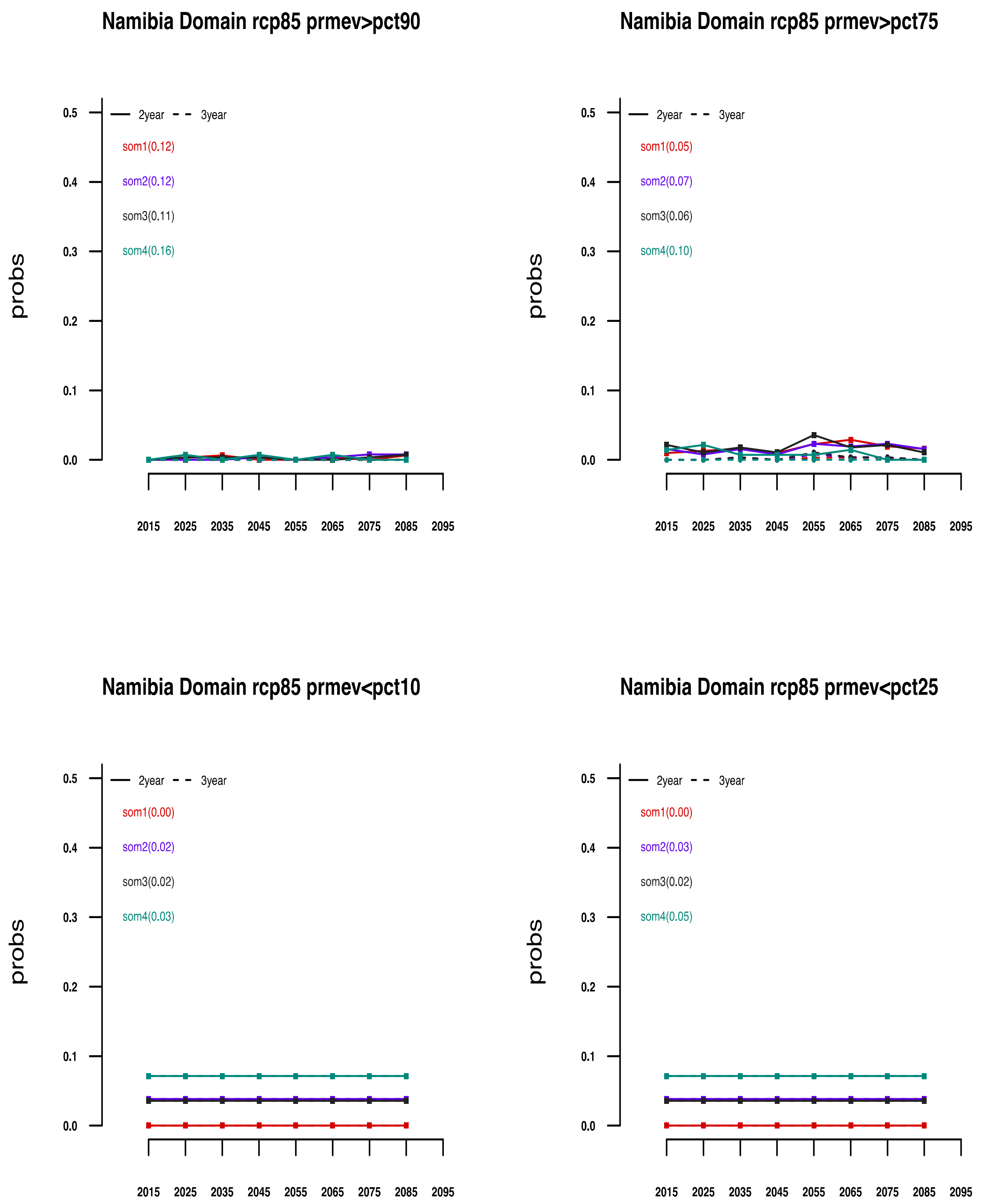


Figure ND20. Decadal probabilities that future annual rainfall less evaporation values will exceed the 90th percentile (top left) or the 75th percentile (top right) or will be below the 10th percentile (bottom left) or the 25th percentile (bottom right) over successive two- and three-year periods based on percentiles for annual rainfall less evaporation calculated for individual models across the base period, 1986-2005. Exceedance probabilities for 2 years are shown as solid lines, for 3 years as dotted lines. Curves for the different soms as in Figure ND19 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.