PROJECT 1.2: SOUTH-WEST WESTERN AUSTRALIA'S REGIONAL SURFACE CLIMATE AND WEATHER SYSTEMS

Principal Investigators

Pandora Hope, Bureau of Meteorology, Centre for Australian Weather and Climate Research, PO Box 1289, Melbourne, Victoria, 3001 (Ph: 03 9669 4774; Email: p.hope@bom.gov.au);

Senior Investigator

Catherine J Ganter, Bureau of Meteorology, Centre for Australian Weather and Climate Research and National Climate Centre, PO Box 1289, Melbourne, Victoria, 3001 (Ph: 03 9669 4679; Email: c.ganter@bom.gov.au)

Objectives

- To determine if seasonal rainfall across the wider South-West is showing new trends in totals or shifts in intensity.
- To determine whether there has been a shift to a new weather regime in recent years.
- To determine whether observed changes are likely to continue into the future.
- To place the current multi-decade rainfall decline in the context of the last few 100 years.

Planned Outcomes

To analyse rainfall totals and intensities in the South-West during the summer and spring, and determine whether there are any trends. An update of the analysis of the winter season will be included also. In addition, detail the different weather systems (identified by a new classification scheme) for summer and spring, and report on how the frequency of these systems have changed in time.

Key Research Findings

The data quality from rainfall recording stations formerly noted for their high-quality and long-term records have been re-assessed. Some stations with long-term, high-quality data have had reductions in quality in recent years for a range of reasons, including the consolidation of farms. This information has fed into Project 1.4.

Annual average rainfall declined in south-west Western Australia in the late 1960s and has not recovered since. A further shift to lower rainfall was identified at approximately the year 2000. The early decline was associated with a decrease in the number of days on which a winter deep low pressure system influenced the region. The recent decline was not associated with a continuing decrease in the number of deep low pressure systems, but rather had a strong contribution from an increase in the number of days when a high pressure system influences the region. New, improved datasets do not alter this picture.

Recent years have also seen extremely high values of winter mean sea-level pressure over SWWA. Both the increased pressures and increased daily occurrence of high pressure systems are as projected for the end of this century by climate models forced with increasing levels of atmospheric greenhouse gases. The magnitudes of the changes expressed by most models suggest that the recent high values might be expected to continue and possibly amplify.

The recent large decline in rainfall in the late 1960s in May to July has persisted and expanded spatially. Both trends and percentage change were analysed to explore this signal. Trends reveal that regions where rainfall did not decline in the late 1960s are now seeing a decline in early winter, whilst the percentage change also suggested a strengthening signal in regions already drying (the far south-west and wheatbelt), a signal that is not so clear using trend analysis.

The interannual variability in the far south-west continues to decline. Trends in the 95th percentile rainfall were generally weak, except along the south coast since 1970 and at Manjimup since 1950. The signal at Manjimup which shows a weakening of the decreasing trend in the extreme rainfall between the 1950-2007 period and the 1970-2007 period supports the findings in Milestone 1.2.1 that recent declines are not associated with a further decrease in the daily occurrence of deep low pressure systems. The stronger trends remain when a more robust statistical technique to calculate the trends was used.

In the summer half year there were minimal trends from both 1950 and 1970 except inland and along the south coast where increases were seen in both totals and, as summer rainfall is dominated by extreme events, extremes.

Analysis of 'standard' seasons was found to potentially 'hide' important information, as found by the analysis of the spring and 'late winter' (August to October) trends. There were only weak trends from 1950, but some stronger trends from 1970 in late winter: increases at Manjimup and Nyerilup and decreases at Peppermint Grove. The map of spring trends showed decreases everywhere. Examining the decadal variability by month revealed that rainfall in August and September had been increasing, but decreasing in October and November.

A new array (self-organising map) of weather 'types' was developed to explore summer rainfall variability. It included fewer types and a measure of lower atmospheric humidity was included. There was little distinction in the amount or spatial distribution of rainfall associated with each different type. Higher rainfall events, that defined the spatial pattern, were associated with tropical low pressure systems or cyclones. The timing of the occurrence of rainfall associated with these did not align with any particular weather type.

Summer maximum temperatures display cooling trends over the last 50 years across the south-west. A self-organising map was developed to explore temperature variations. The spatial distribution of maximum temperature associated with each synoptic type was quite distinct. This is being explored further to better understand the observed cooling trend.

Milestone Reports:

Milestone 1.2.1 *Note on the frequency of winter weather systems impacting the South-West in the last few years* **(Completed 31/12/2009)**

This milestone has been completed and was reported on extensively in the IOCI3 Report 1.

Milestone 1.2.2 *Report on the rainfall variability and trends in all seasons – has there been a shift in rainfall intensity over the last 40 years* (Completed 31/12/2009)

This milestone has been completed and was reported on extensively in the IOCI3 Report 1. A few minor points have been added here for completeness.

Month-by-month decadal variability

In the project milestone table from the previous report, we stated that we would use the new AWAP gridded dataset, which accounts for topography. The decadal variability for each month as averaged over the south-west 'IOCI' triangle using this new data is shown in Figure 1. This plot has now been updated to 2009.

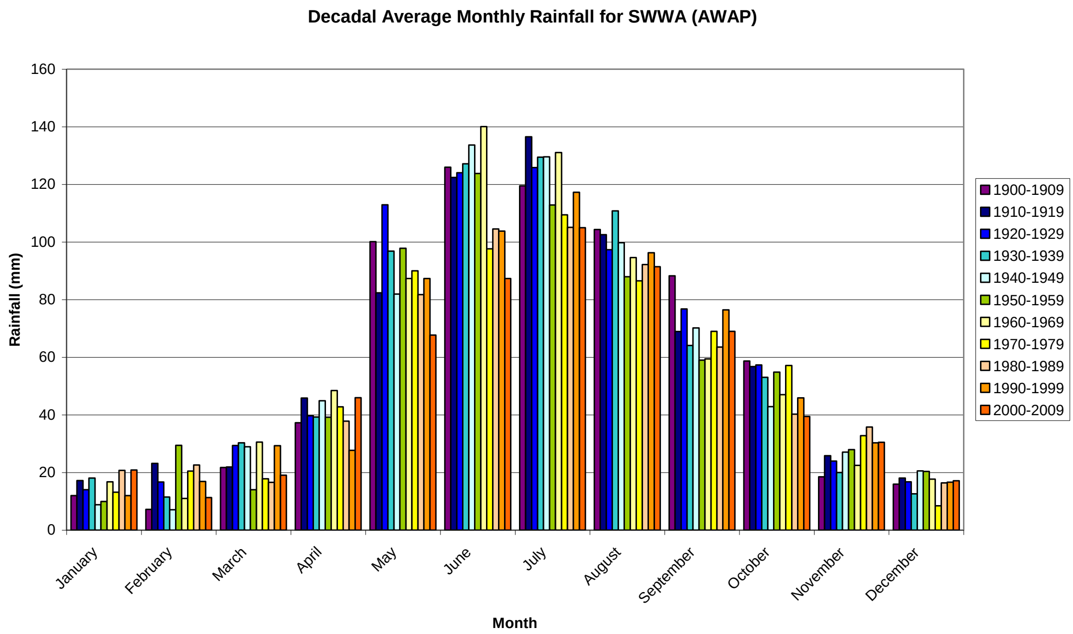

Figure 1. Decadal variability of monthly totals using new AWAP dataset

Compared to the older version (Figure 2), the totals are larger as would be expected when topographic effects are included (higher rainfall at higher elevations), but the decadal variability tells the same story. Including the two most recent years data also does not change the story.

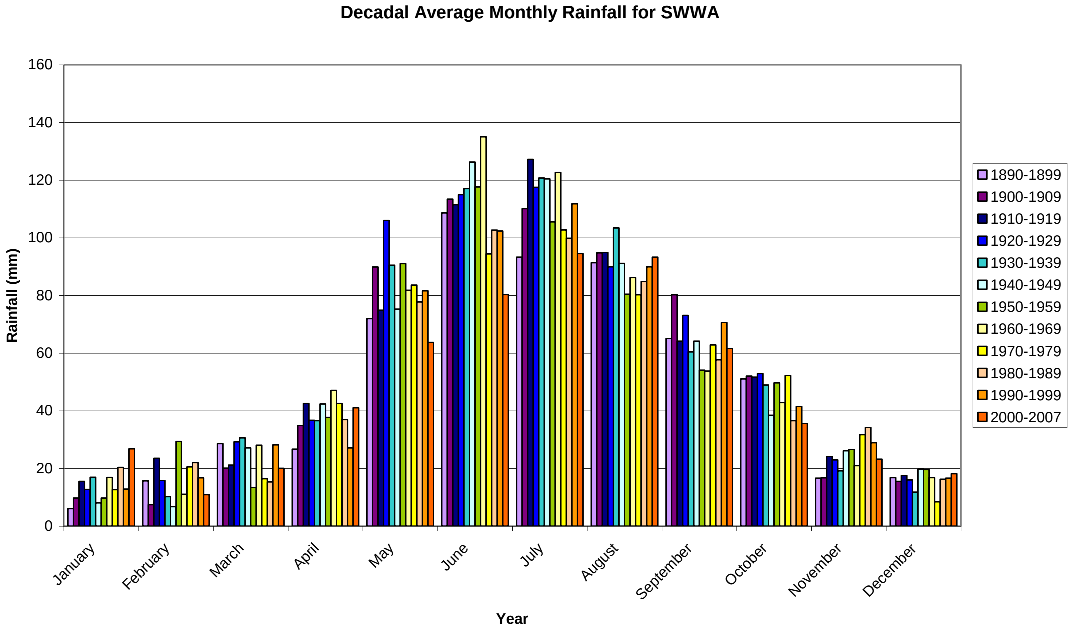

Figure 2. Decadal variability of monthly totals using grids from Barnes analysis.

Impact of method of trend calculation

All the linear trends reported in the last milestone report were re-calculated using the non-parametric Kendall tau test (as used by Alexander et al. 2007). This test is more robust than a standard linear trend calculation since prior assumptions do not have to be made about the distribution of the time series. Examining the differences in results for rainfall trends from 1950 to 2007 revealed a reasonable amount of variability for trend values close to zero, however, more dramatic trends were all captured with both methods, with values of similar magnitude. There was no systematic difference in the results from the two methods – i.e. no one method consistently produced trends of greater magnitude than the other. Thus the results tables presented in the previous milestone report are a good reflection of the observed trends.

References

Alexander, L. V., P. Hope, D. Collins, B. Trewin, A. Lynch, and N. Nicholls, 2007: Trends in Australia's climate means and extremes: a global context. *Australian Meteorological Magazine*, **56,** 1-18

Milestone 1.2.3 Report on the range of weather systems identified by the new classification scheme for South-West summer weather systems.

(Progress report – to be completed 31/12/2010)

Summary and key points

A new array (self-organising map) of weather 'types' was developed to explore summer rainfall variability. It included fewer types and a measure of lower atmospheric humidity was included. There was little distinction in the amount or spatial distribution of rainfall associated with each different type. Higher rainfall events, that defined the spatial pattern, were associated with tropical low pressure systems or cyclones. The timing of the occurrence of rainfall associated with these did not align with any particular weather type.

Summer maximum temperatures display cooling trends over the last 50 years across the south-west. A self-organising map was developed to explore temperature variations. The spatial distribution of maximum temperature associated with each synoptic type was quite distinct. This is being explored further to better understand the observed cooling trend.

Introduction

During IOCI Stage 2, extensive research was performed on wintertime circulation changes in far southwest Western Australia (Ryan and Hope, 2005 Ryan and Hope, 2006). In this progress report, trends in summer rainfall and temperature are considered, and the types of weather systems that are associated with them are explored.

Summer (December, January, February) rainfall totals are low across south-west Western Australia[1], and trends are minimal[2]. Temperatures across the south-west in summer show a cooling trend in maximum temperatures, based upon the old network of high-quality stations. When the new set developed under IOCI project 1.4 becomes available this will be re-addressed. In order to explore the weather systems associated with the range of temperature conditions and rainfall events that occur, a Self-Organising Map (SOM) was developed to represent summertime conditions. This was done initially with specific attention to considering the association with rainfall events, then subsequently a SOM is currently being developed to highlight associations with maximum temperature patterns and variability. The knowledge gained from developing a SOM for the winter situation was used as a starting point (Hope et al., 2006).

Development of Self Organising Map

A self-organising map uses the continuum of daily weather situations to guide the development of a pre-defined number of weather 'types'. For summer, two months, January and February (until 28th only), were focussed upon. The spatial domain chosen includes more of the tropics than used by Hope et al. (2006): 90-135ºE and 7.5-50ºS. An array of 3x4 types was chosen – fewer than for winter since there is lower day-to-day variability in summer.

A range of atmospheric variables from National Centers for Environmental Prediction/National Center for Atmospheric Research reanalyses were considered for inclusion to best represent the dominant weather systems and their

[1] http://www.bom.gov.au/cgi-bin/climate/change/averagemaps.cgi
[2] http://www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi

association with rainfall and maximum temperature. The mean sea-level pressure (MSLP) was first considered as it is an excellent field for describing weather systems at this latitude. The height at 500 hPa was also considered, as this is seen as the 'steering height' that often signals weather activity to come, and the low-level specific humidity of the atmosphere (q850) was also considered as this has been found to be a useful predictor for downscaling rainfall in the region (Timbal et al., 2008). Each combination of these three variables were assessed, and MSLP and q850 were considered the most appropriate combination to describe the range of weather systems over the south-west during summer in reference to rainfall, but just MSLP was used for exploring the temperature signature. Different times were also considered, and, to best capture the conditions during the hottest part of the day to explore the trend in maximum temperature, the 06:00Z (14:00 WST, i.e. Perth time) times were used. The final SOM for rainfall is shown in Figure 1.

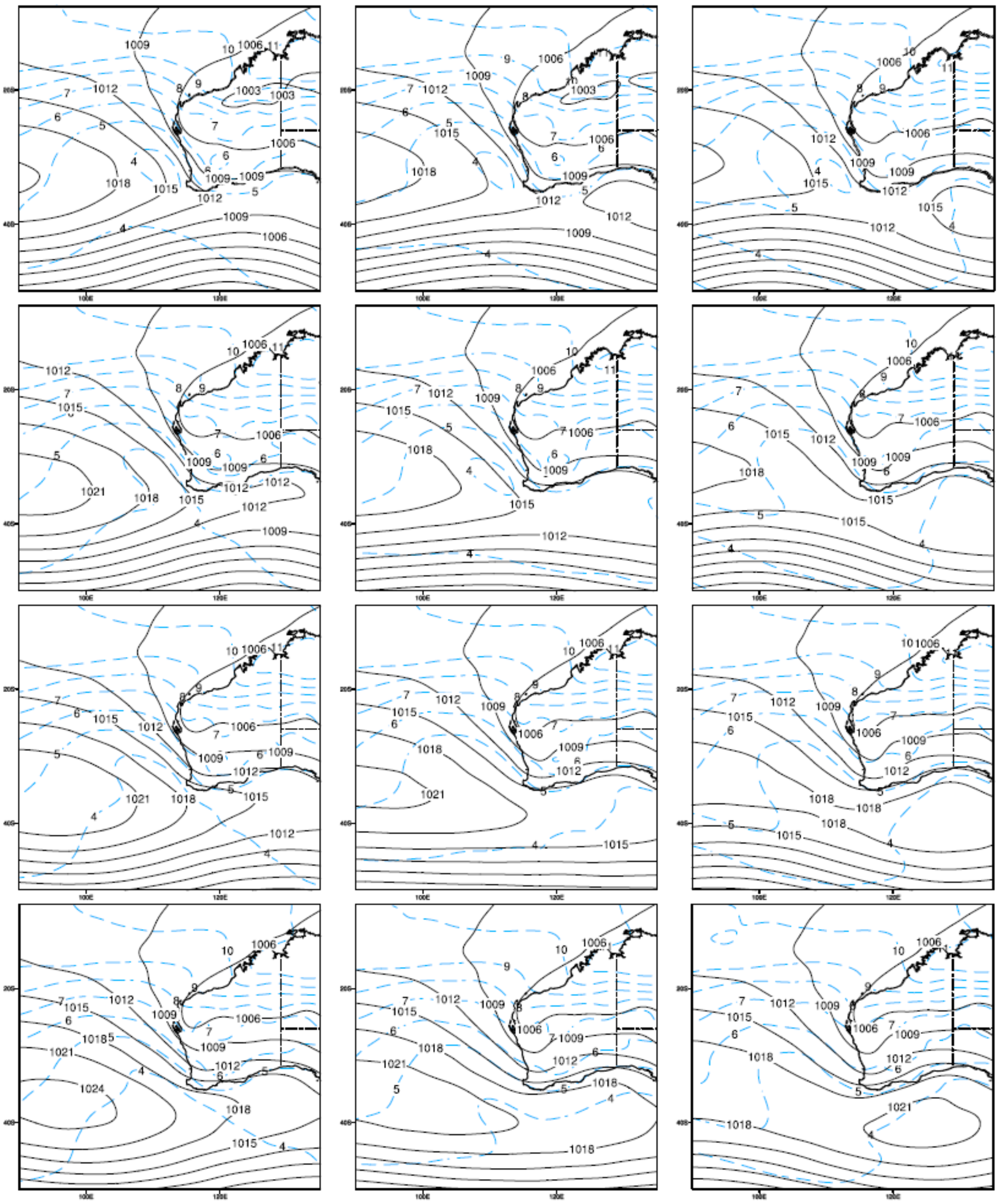

Figure 1. SOM pattern for January and February for MSLP and specific humidity at 850 hPa.

Summer Rainfall

The daily rainfall values corresponding to each SOM type were plotted (Figure 2). There is little variability between each type, most showing a band of higher rainfall through the middle of the region. The pattern of this rainfall seems to be related to the decay of tropical cyclones. This hypothesis was strengthened after examining the top 10 rainfall events and finding that each was associated with a tropical cyclone or low (Table 1).

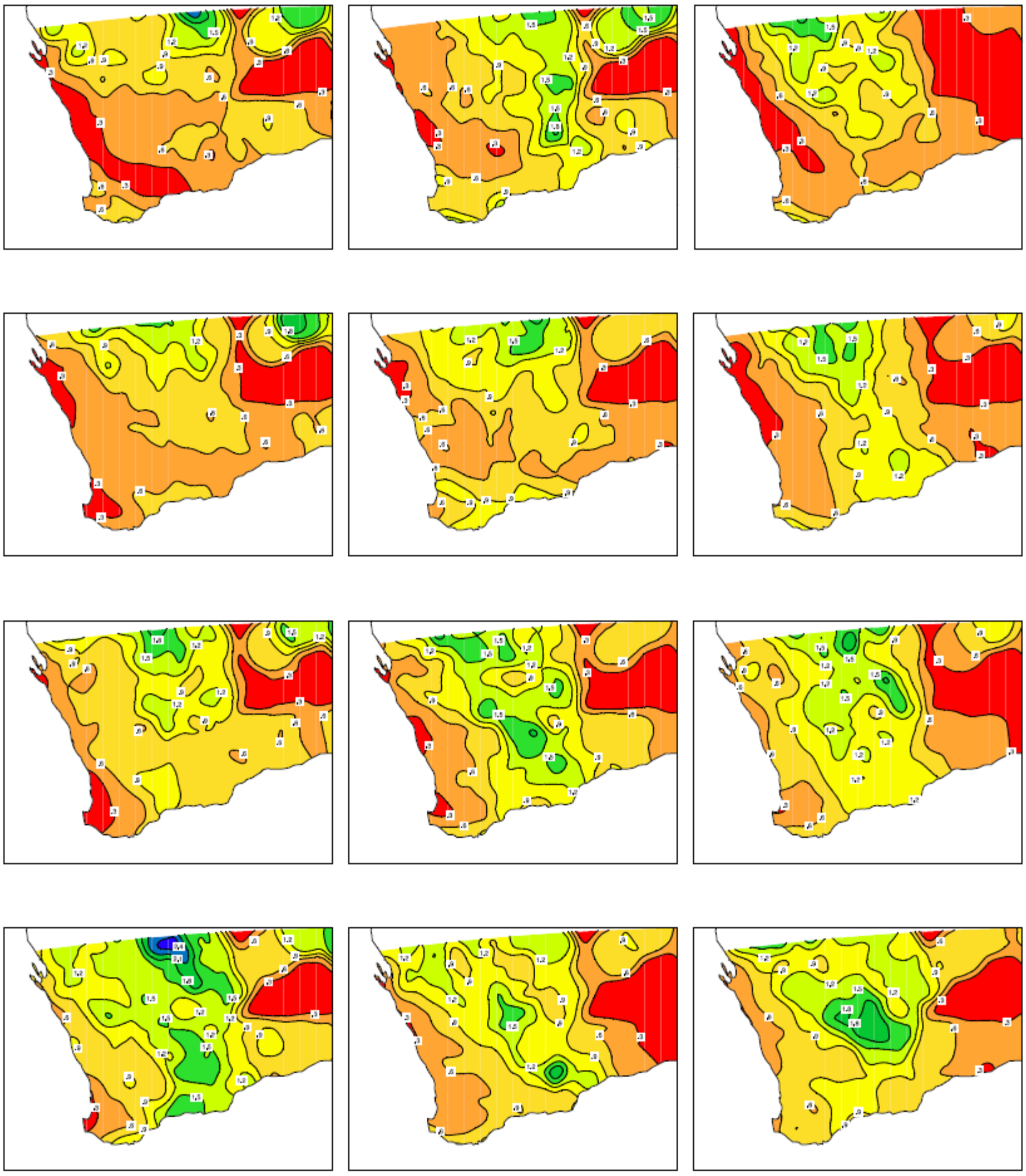

Figure 3. Daily rainfall totals, associated with the SOM shown in Figure 1. Image is west of 130E and south of 25S.

Table 1. Top ten rainy January/February days for the region south of 25S, and west of 126E for Western Australia.

Rank	Year	Month	Day	Area Averaged Rainfall (mm)	Associated Tropical system
1	1995	02	27	39.795	TC *Bobby*
2	1948	02	22	38.078	TC (unnamed)
3	2000	01	23	32.629	Depression
4	2007	01	04	30.208	Tropical Low *Isobel*
5	1948	02	23	29.374	TC (unnamed)
6	1967	01	23	26.69	TC *Elsie*
7	1970	02	17	26.47	TC *Ingrid*
8	1975	02	22	20.937	TC *Trixie*
9	1987	01	22	20.128	TC *Connie*
10	1995	02	26	19.647	TC *Bobby*

Of these top ten rain days (one example shown below in Figure 4), eight of the ten were associated with a tropical cyclone. For the remaining two of the top ten, one was associated with a tropical depression, and the other with tropical low *Isobel*. Two sets of days, number 1 and 10, and also number 2 and 5 occurred during the same tropical cyclone. Further investigation of the top 30 days with the heaviest rainfall revealed that several of the heavy rain days were associated with the same tropical system. Tropical cyclone *Bobby*, for example, occurred during the 19th to the 27th of February in 1995 and four days in the top 30 were associated with it.

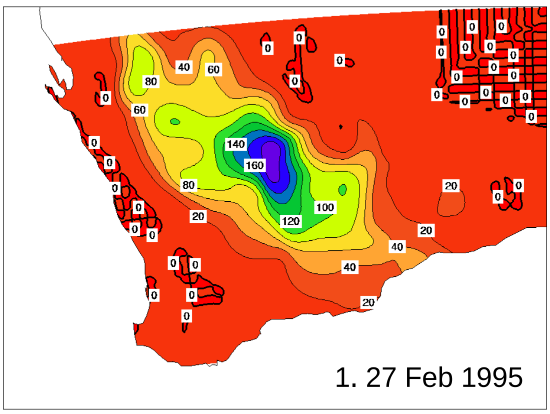

Figure 4. A typical example of rainfall pattern in the daily top ten rainfall days for January and February, for the time period of 1948-2008

The pattern on the rain day in Figure 4 is indicative of the patterns shown on almost all high rainfall days. Thus this is the pattern associated with the breakdown of a tropical low or cyclone. This pattern closely matches the patterns in Figure 3 associated with many of the weather types. With some values in the order of 160 – 200mm for a daily value, these would appear to be a major contributor to the SOM rainfall patterns.

This particular pattern of high rainfall was not associated with any particular circulation type in the SOM. Table 2 shows the top 10 rain days and their corresponding SOM type – no more than two match any one type. This shows that circulation types are not strong drivers of rainfall variability across the south-west in summer.

Table 2. SOM type that the top ten rain days in January and February fall into. The 'Type' column refers to the self organising map (SOM) types in Figures 2 and 3. The first number in the 'Type' column refers to the column of SOMs while the second number refers to the rows of SOMs in Figures 2 and 3, for example the top left corner SOM is 0,0, the second along the top is 1,0 and the bottom right type is 2,3.

Rank	Type
1	1,3
2	0,3
3	2,2
4	0,1
5	1,2
6	2,1
7	1,1
8	2,2
9	2,0
10	1,3

Summer maximum temperature

A SOM has been developed to best represent variability in summer maximum temperature (Figure 5). It was found that MSLP at the height of the afternoon was the best descriptor of the circulation associated with temperature variability. The aim is to explore the drivers behind the cooling trend across the region. The patterns of temperature anomalies that correspond with this newly developed SOM are very distinct (Figure 6). The analysis of what these different weather types mean for summer temperature variability and trends will be reported upon when this milestone is completed at the end of 2010.

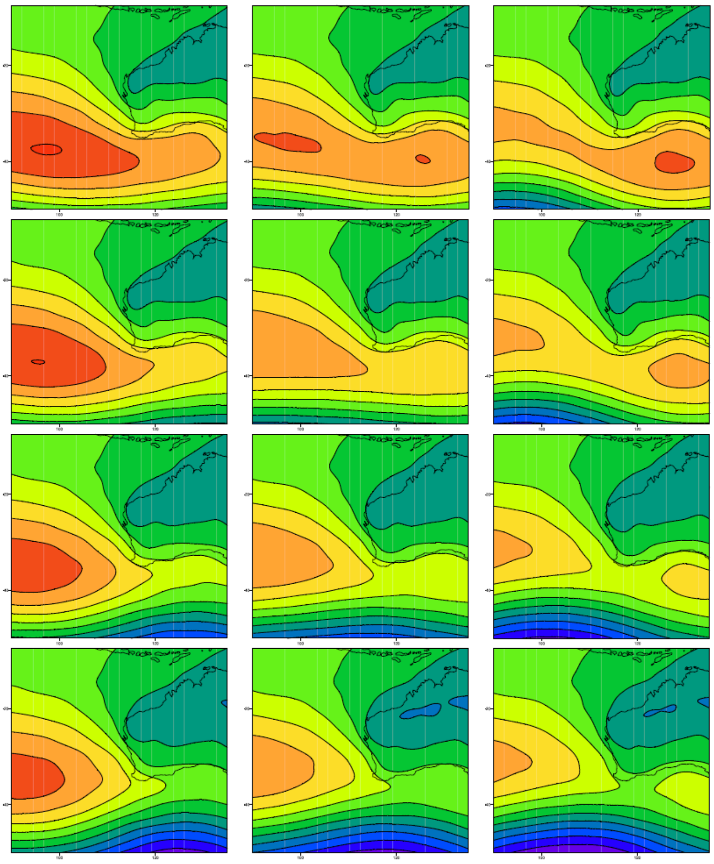

Figure 5. SOM pattern for January and February for examining temperature variability – MSLP at 06:00Z

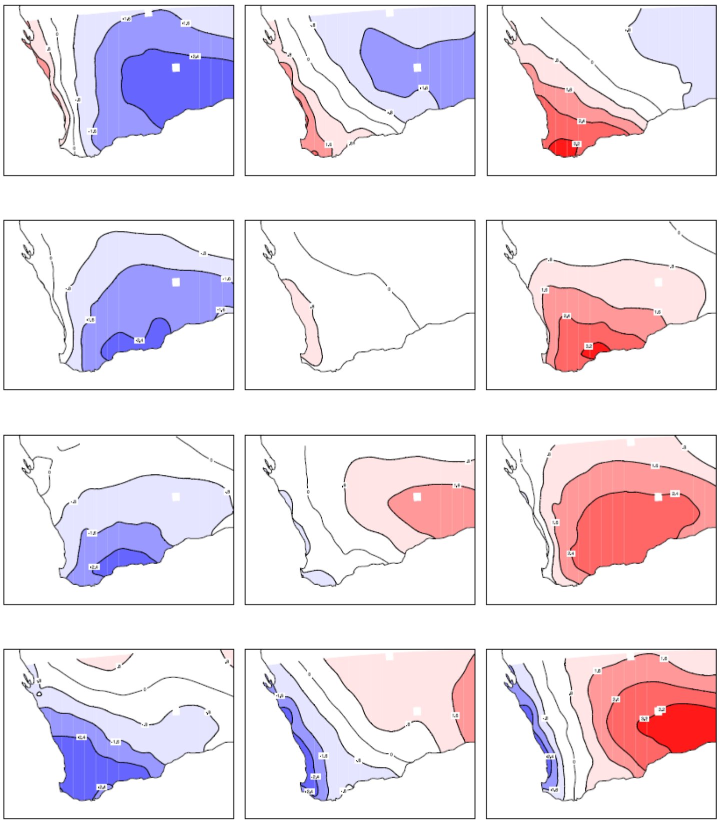

Figure 6. Daily maximum temperature anomalies, associated with the SOM shown in Figure 5. Image is west of 130E and south of 25S

References

Hope, P. K., W. Drosdowsky, and N. Nicholls, 2006: Shifts in synoptic systems influencing south west Western Australia. *Climate Dynamics*, **26,** 751-764.

Ryan, B. and P. Hope, Eds., 2005: *Indian Ocean Climate Initiative Stage 2: Report of Phase 1 Activity*. *Technical Report*, Indian Ocean Climate Initiative Panel, 40 pp.

——, Eds., 2006: *Indian Ocean Climate Initiative Stage 2: Report of Phase 2 Activity*. *Technical Report*, Indian Ocean Climate Initiative Panel, 37 pp.

Timbal, B., Z. Li, and E. Fernandez, 2008: The Bureau of Meteorology statistical downscaling model graphical user interface: user manual and software documentation, 90 pp.

Milestone 1.2.4 *Report on the range of weather systems identified by the new classification scheme for South-West spring and autumn weather systems*. (Progress report – to be completed 31/12/2010)

Introduction

Up until this point, methods to classify the range of weather systems influencing south-west Western Australia under the IOCI have been developed for seasons at the extremes of the seasonal cycle. During these times the subtropical ridge is positioned at its most northerly location (winter) or most southerly location (summer). The latitudinal extent of weather systems will thus be limited by this strong climatological feature. During the transition seasons (spring and autumn), systems may be less constrained latitudinally and thus methods to classify weather systems that apply to fixed locations might be less useful. The self-organising maps described in Milestones 1.2.1 and 1.2.3 assume a spatial stationarity. Understanding the variability of weather systems during the transition season might require an alteration to the method or a different style of classification.

Background Motivation

The declining rainfall in autumn is an obvious driver to better understand the range of systems influencing south-west Western Australia during this season. Many studies have assumed that weather systems have shifted south, and a classification method that can identify spatial shifts in the weather systems might finally allow an unequivocal statement about any latitudinal change of the systems.

Little trend in spring rainfall has been observed, however, there are other reasons to explore the variability of weather patterns in this season. Discussion with scientists within the Western Australian Marine Science Institution (Ming Feng) led to a question about why there was a low settlement rate of rock lobster along the south-west coast in 2008. The winds associated with various weather patterns are a key component to driving the water transports in the region that allow rock lobster settlement, thus a classification system that clearly identifies the wind directions associated with different weather types could prove highly informative in understanding these changes.

Methods

A number of different methods have been explored, but the development of an appropriate method for autumn and for spring is still in process. One option that we are currently trialling is to simply increase the number of synoptic types in a self-organising map to include a stationary snap-shot of the weather systems that occur at varying latitudes. We hope to settle on a final method soon and report on results in the final milestone report in the 2010 report.

Summary of new linkages to other IOCI3 Project

The findings from the work done in analysing the data quality at stations across the south west for the study of extremes was used in Project 1.4.

Summary of any new research opportunities that have arisen

A research project for Managing Climate Variability (McIntosh, 2008) led to an examination of a number of different methods to identify frontal systems that bring rainfall to the wheat belt in winter, resulting in a conference presentation (Hope et al. 2009, 9ICSHMO) and an article in preparation.

Alterations to research plans

Introduce an analysis of temperatures for the summer synoptic analysis.

Next steps planned

Continue to research the drivers of summer-time temperature to best produce a relevant synoptic classification method. Continue to appropriate methods of classifying the synoptic systems in autumn and spring.

List of Publications Accepted and Submitted

Hope, P. and C.J. Ganter, 2010: Recent and projected rainfall trends in south-west Australia and the associated shifts in weather systems. In: Book of Proceedings from Greenhouse 2009 Conference. CSIRO publishing. in press.

Hope, P. and B. Timbal and R. Fawcett, 2009: Associations between rainfall variability in the southwest and southeast of Australia and their evolution through time. International Journal of Climatology **30**; 1360-1371.

List of IOCI-Related Presentations at National of International Conferences, Symposia and Workshops

Nil