Multi-model analysis of expected future trends in the landfall of tropical systems from the Southwest Indian Ocean over the eastern parts of southern Africa

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ABSTRACT

An analysis was performed on the simulations of various Global Circulation Models regarding the change in favourability of broad circulation anomalies in the lower atmosphere for landfall and further westward penetration of tropical systems from the southwest Indian Ocean (SWIO) over southern Africa as well as the simulated change in the frequencies, tracks and intensities of landfalling low-pressure systems in the context of climate change. The main finding in this regard is that there exists general consensus between various climate simulations that the conditions in future will be more conducive to the landfall and further westward movement of tropical systems from the SWIO. In the light of the contribution by these systems to heavy rainfall events over the area, this could have significant socio-economical implications.

1. INTRODUCTION

Tropical systems from the SWIO contribute a significant portion of multi-day heavy rainfall events over the eastern interior of southern Africa. For example, the devastating floods during 1996 over parts of the Limpopo River Basin (Crimp and Mason, 1999) and in February 2000 (Reason and Keibel, 2004) were the result of this type of event.

In the light of the important contribution to heavy rainfall events in the area, the impact of projected climate change on tropical systems making landfall needs to be understood. Changes in frequency, intensity and landfall position of these systems and the favorability of the general lower atmospheric circulation are taken into account.

2. MATERIALS AND METHODS

2.1 Data

Data from four Global Circulation Models - three Coupled Global Circulation Models (CGCMs) and one high-resolution Atmospheric Global Circulation Model (AGCM) - were analyzed and the simulations of current and future conditions were compared. The simulations of the three CGCMs were specifically produced for the Intergovernmental Panel on Climate Change (IPCC) 4th Assessment Report (AR4). In the simulations for the period 1970-2000, observed greenhouse gas concentrations were used to specify the anthropogenic forcing. For simulation of future conditions (2080-2100), greenhouse gas concentrations projected under the IPCC Special Report on Emissions Scenarios (SRES) A2 scenario were used to force the models.

2.2 SOM analysis

A non-linear classification approach known as a Self Organizing Map (SOM) (Kohonen, 1996), and that has previously been applied to synoptic weather data (Hewitson and Crane, 2002) was applied to categorize daily synoptic data into broad synoptic conditions. These were then evaluated according to their favorability for the landfall of tropical systems from the SWIO directly responsible for precipitation over the eastern interior of southern Africa.

The spatial domain include the areas dominated by the South Atlantic and South Indian Ocean high-pressure systems as well as areas further north where tropical systems dominate. The SLP values were also standardized. A 6X6 SOM array was found to be effective for the purposes of this study.

From the favourability of each node for the landfall and westward movement of tropical systems from the SWIO and the total occurrence of each node in simulation of current and future conditions, the percentage of days expected with tropical systems moving inland from the SWIO were calculated for current and future conditions

2.3 Tracking of low pressure areas

Because of large data volumes, tracking algorithms have previously been applied for the identification and tracking of low pressure systems in Global Circulation Models to evaluate amongst others the future behaviour of tropical cyclone-like vortices (Walsh and Katzfey, 2000). In this study, a closed-low finding-and-tracking algorithm based on the identification of all SLP minima and the temporal tracking of these minima subjected to various tracking criteria were performed. The tracking algorithm was applied to the Sea Level Pressure Fields of all three datasets at a daily time resolution and 2.5° spatial resolution. The spatial domain and other tracking algorithm variables remained exactly the same for all datasets. The algorithm was applied to current (1981-2000) and future (2081 – 2100) GCM simulations. The number of tracks representing low-pressure systems making landfall per model simulation were counted. Additionally, the position of landfall and the minimum pressure of all landfalling systems prior to landfall were also recorded.

3. RESULTS AND DISCUSSION

3.1 General favourability of the lower atmosphere

The clustering of nodes representing conditions favourable for the landfall and westward movement of tropical systems from the SWIO can be seen in Figure 3.2

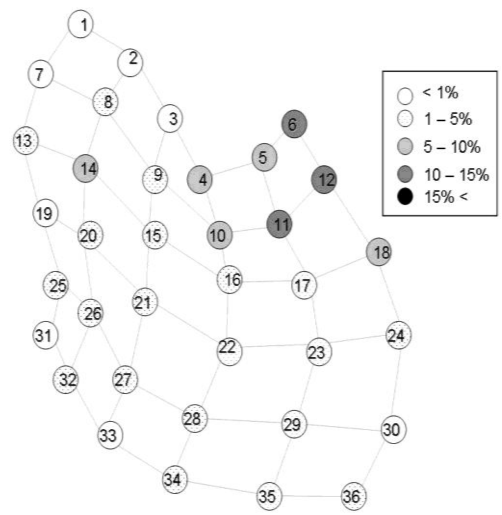

Figure 3.1 A three-dimensional representation of the nodes (vectors) produced by the 6X6 SOM analysis of on standardized sea level pressure NCEP Reanalysis data. The percentage of days with tropical systems moving from the SWIO into the eastern parts of southern Africa during each of the nodes are indicated in shades of grey.

The change in the calculated expected percentage of days with the studied synoptic sequence is shown in Figure 3.2.

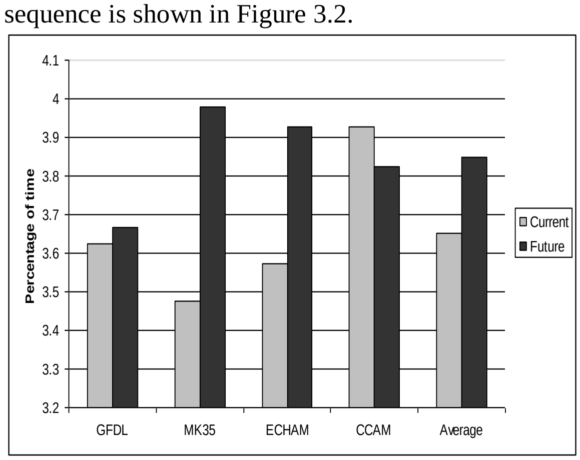

Figure 3.2 The expected percentage of days that tropical systems from the SWIO moves into the eastern interior (current = grey and future = black).

3.2 Behaviour of closed low pressure systems from the SWIO

The tracking of closed low pressure systems from the SWIO into the eastern parts of southern Africa has revealed consistent results amongst the GCMs studied. There is an increase in the landfall of closed low pressure systems according to the simulations of all GCMs. Figure 3.3 shows the number of landfalls for each 20-year period (current and future) for the various models as indicated.

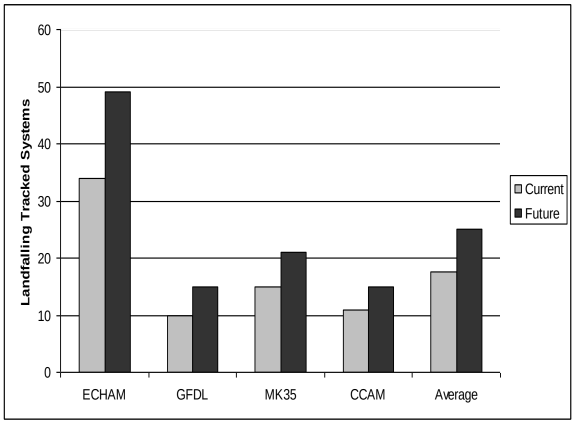

Figure 3.3 The number of landfalling low-pressure systems tracked within current and future simulations of the GCM's as indicated.

While there is a simulated increase in the total number of closed low pressure systems making landfall over the eastern coastal areas, there is also a slight northward shift in the preferred position of landfall (Figure 3.4)

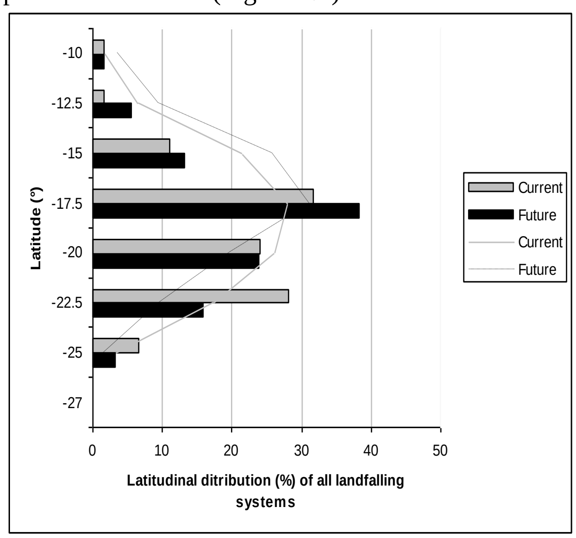

Figure 3.4 Average percentage-wise latitudinal distributions of landfall positions of closed low pressure systems (current = grey, future = black)

A slight decrease in the lowest pressure before landfall (not shown) has also been found between low pressure system simulated for current and future conditions.

4. CONCLUSION AND RECOMMENDATIONS

There is consensus amongst the simulations of daily SLP fields of four Coupled Global Circulation Models (CGCMs) regarding the following changes pertaining to tropical systems making landfall over the eastern parts of southern Africa:

- Slightly more favourable general conditions in the lower atmosphere surrounding southern Africa for the landfall and further westward movement into the interior of tropical systems from the SWIO
- An increase in the number of systems from the SWIO making landfall
- A slight northward shift in the preferred landfall position
- An increase in the intensity of systems making landfall from the SWIO

5. ACKNOWLEDGEMENTS

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6. REFERENCES

Crimp, S. J. and Mason S. J. (1999) The Extreme Precipitation Event of 11 to 16 February 1996 over South Africa. *Meteorology and Atmospheric Physics,* **70,** 29-42. DOI: 10.1007/s007030050023.

Reason, C. J. C. and Keibel, A. (2004) Tropical Cyclone Eline and its Unusual Penetration over the Southern African Mainland. *Weather and Forecasting,* **19,** 789-805. DOI: 10.1175/1520-0434(2004)019.

Walsh, K. J. E. and Katzfey J. J. (2000) The impact of climate change on the poleward movement of tropical cyclone-like vortices in a regional climate model. *Journal of Climate*, **13**, 1116-1132.

Kohonen, T. (1995) Self Organizing Maps. *Springer series in Information Sciences,* **30,** Springer-Verlag: Berlin, 362 pp.

Hewitson, B. C. and Crane R. G. (2002) Self-organizing maps: applications to synoptic climatology. *Climate Research*, **22,** 13-26.