ELSEVIER

Journal of Arid Environments 70 (2007) 604–614

Journal of Arid Environments

www.elsevier.com/locate/jaridenv

Namaqualand's climate: Recent historical changes and future scenarios

N.C. MacKellar*, B.C. Hewitson, M.A. Tadross

Climate Systems Analysis Group, Department of Environmental and Geographical Science, University of Cape Town, Private Bag, Rondebosch 7701, Republic of South Africa

Received 25 July 2005; received in revised form 14 March 2006; accepted 15 March 2006
Available online 22 May 2006

Abstract

A brief outline of some issues concerning global climate change research is presented before discussing local-scale changes in Namaqaland's rainfall. Using a gridded data set derived through interpolation of station records, trends in observed rainfall for the period 1950–1999 are discussed. To assess what changes may occur during the 21st century, the downscaled results of six different General Circulation Model projections are presented. The historical trends show some clear spatial patterns, which depict regions of wetting in the central coastal belt and the north-eastern part of the domain, and extensive drying along the escarpment. Reasonably good agreement is shown by the different downscaled projections. These suggest increased late summer convective precipitation in the north-east, but extensive drying along the coast in early and mid winter consistent with the poleward retreat of rain-bearing mid-latitude cyclones.

Keywords: Namaqualand; Climate change; Rainfall; Downscaling

1. Introduction

1.1. Some issues concerning climate change research

Climate change is a highly topical issue in today's society. Its impacts extend across the physical, natural and social domains and are thus of importance to researchers in a wide

*Corresponding author. Tel.: +27 21 650 2784; fax: +27 21 650 5773.
E-mail address: neil@egs.uct.ac.za (N.C. MacKellar).

0140-1963/$ - see front matter
doi:10.1016/j.jaridenv.2006.03.024

range of disciplines. There is therefore a clear demand for reliable information regarding both past and future climate, but there are many uncertainties and caveats that restrict our knowledge of the climate system and climate change.

Station records provide the most direct measurements with which one can study historical trends in climate, but these can be unreliable, with large gaps often appearing in station time-series. Poor spatial coverage of stations is another problem, which is particularly evident in sparsely populated arid regions. Since a station represents only a single point, it may not be adequately representative of the surrounding region, especially in the presence of complex environmental gradients and highly cellular convective rainfall. To help overcome this, much work has been done to produce gridded data sets from existing station records in order to approximate the true spatio-temporal variability of climate variables (e.g. New et al., 2000; Hewitson and Crane, 2005). These gridded products are useful for many different applications, including historical analysis, vegetation and hydrological modelling, validation of climate model output, and climate downscaling. As is discussed below, this study makes use of one such product.

When one attempts to make projections of what the future climate may be, many more uncertainties are introduced (e.g. Allen et al., 2000; Weaver and Zwiers, 2000; Stott and Kettleborough, 2002). The primary tool for climate projections is the General Circulation Model (GCM), which is a numerical representation of the earth's atmosphere, oceans and land surface. Many different GCMs are in operation, each with different assumptions and parameterizations regarding the various physical processes. Sub-grid scale processes, such as cloud formation and precipitation, are particularly difficult to simulate and a variety of schemes exists to represent these. The land surface plays a very important role in the surface energy and water balance, but is also problematic to represent (Crossley et al., 2000). It is therefore clear that—complex and sophisticated as GCMs are—these models are by no means perfect representations of the climate system. Non-linear feedback and the inherently chaotic nature of the climate system (Lorenz, 1993; Palmer, 1999) make the task of climate modelling that much more difficult.

To derive a projection of future climate, a GCM is forced with a change in atmospheric chemistry as prescribed by an emission scenario. A group of scenarios for the 21st century is presented in the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES; Nakićenović et al., 2000). These scenarios are based on various assumptions about how the global economy will evolve over the upcoming century, and what the associated greenhouse gas emissions will be. These range from major reductions in global emissions to an acceleration in fossil fuel use and rapid increase in emissions. So, in addition to the caveats inherent in climate modelling, there is uncertainty about the true magnitude of anthropogenic forcing.

Spatial scale is yet another problem encountered by climatologists. GCMs, with typical grid sizes of 300–500 km, are skillful at the global, hemispheric and synoptic scales, but to use raw GCM output to evaluate a region, the size of Namaqualand would not be appropriate. To overcome this problem, various methods of downscaling have been developed (Murphy, 1998; Giorgi et al., 2001). The dynamical approach uses a Regional Climate Model (RCM), which is a numerical model with a much smaller grid size than a GCM and is nested within a GCM simulation (Takle et al., 1999; Pan et al., 2001). Statistical or empirical methods provide a computationally cheaper alternative to dynamical downscaling (Wilby et al., 1998; Hewitson and Crane, in press) and form the basis for the climate projections for Namaqualand discussed in this paper.