January and July climate simulations over the SADC region using the limited-area model DARLAM

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Abstract

High-resolution climate simulations of near-surface variables are presented for January and July over the Southern African Developing Countries (SADC) region using the CSIRO Division of Atmospheric Research Limited-Area Model (DARLAM) nested within a General Circulation Model (GCM). The model domain includes tropical (north and south of the equator) and sub-tropical (Southern Africa) regions. Objective measures of skill are used to assess the quality of model simulations, and the performance of the model is verified over various subregions of the model domain. South of the tropics, DARLAM fields are not only superior to those produced by the GCM, but also compare well with mesoscale observations. This is particularly true for the spatial distribution of rainfall and screen temperature simulations. DARLAM, however, severely over-estimates rainfall totals over regions of steep orography.

Introduction

Mesoscale atmospheric circulation systems and surface forcing have an important influence on the climate of sub-Saharan Africa. For example, the steep escarpment of southern and eastern South Africa induces the occurrence of large spatial differences in rainfall totals over relatively short distances (Engelbrecht and Rautenbach, 2000). In central Africa, mesoscale forcing over Lake Victoria results in what is probably the highest frequency of thunderstorms in the world (Asnani, 1993), while exceptionally strong sea-breeze circulation cells are responsible for the dominant winds along the coastlines of Madagascar and Namibia (Jackson, 1954).

On the synoptic scale, most general circulation models (GCMs) succeed to adequately simulate the main characteristics of the general circulation over Southern Africa (Joubert, 1997). However, at this point in time computational requirements prevent GCMs from performing climate simulations at mesoscale resolutions of a few kilometres to about 100 km (Giorgi and Mearns, 1991; McGregor et al., 1993a). A technique known as nested climate modelling (NCM) has therefore been introduced as a computationally feasible alternative to obtain high-resolution climate simulations over limited areas of the earth. NCM involves the nesting of a high-resolution limited-area model (LAM) within the grid of a GCM over the area of interest. With a relatively finer horizontal resolution, the LAM may then succeed to capture some of the mesoscale properties of the atmospheric circulation.

The Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Atmospheric Research Limited-Area Model (DARLAM) has been used for climate modelling experiments over many locations of the world at a variety of horizontal and vertical resolutions. Most simulations have been performed by nesting DARLAM either within the CSIRO-9 GCM, or within observational analyses, over Australian domains. A one-way nesting technique was employed in all the DARLAM simulations. In the one-way nesting approach the LAM simulations are not allowed to interact with and influence the driving GCM analyses. The earliest simulations were for perpetual January conditions (McGregor and Walsh, 1991; 1993). Subsequently, multiple January and July simulations have been performed (Walsh and McGregor, 1995), followed more recently by full seasonally varying simulations of up to 20 years duration (McGregor, 1999). The latest mesoscale climate simulations were nested for 140 years within a CSIRO-9 GCM transient simulation. In these simulations DARLAM utilised horizontal grid resolutions of 125 km and 60 km with 9 levels in the vertical (McGregor, 1999). In general it was found that the LAM simulations, especially at higher latitudes, were superior to the associated GCM simulations and compared well with regional observations over the Australian continent.

Joubert et al. (1999) used DARLAM to simulate the January climate over a domain covering Africa south of the equator. Using a one-way nesting procedure, lateral boundary and initial conditions were supplied by the CSIRO-9 GCM. The experiment consisted of 20 January ensemble members nested individually at 125 km x 125 km resolution within the GCM. It was found that DARLAM captured the spatial pattern of observed rainfall and inter-annual rainfall variability over the region as a whole more accurately than the GCM. Over the steep eastern escarpment of South Africa, DARLAM produced more rainfall than the GCM and significantly more than observed. In general, DARLAM produced a more accurate and detailed simulation of the January climate over Southern Africa than the coarse resolution GCM. This is largely attributed to the fact that regional geographical features, which influence the climate of Southern Africa, are more clearly resolved by the 125 km x 125 km LAM resolution (Joubert et al., 1999).

This paper describes results from a new initiative where even higher resolution (60 km x 60 km horizontal grid resolution) DARLAM climate simulations have been performed using a domain of 100 x 100 grid points that covers the entire area (Fig. 1) of the Southern African Developing Countries (SADC). The size of the domain is not only larger than in any previously performed high-resolution climate simulations over Southern Africa, but also has

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