Simulations of Southern African climatic change by early-generation general circulation models

Alec Joubert
Climatology Research Group, University ofthe Wltwatersrand, PO Wits 2050, Johannesburg, South Africa

Abstract

Early-generation equilibrium climale models display general agreement concerning possible changes in surface air temperalure and mean sea level pressure for the Southern African region under doubled carbon dioxide conditions. There is consensus amongst the models considered that the entire region will become warmer and that tropical, subtropical and mid-latitude circulation systems will weaken and shift southward. Considerably less agreement exists concerning possible changes in precipitation. Encouragingly, though, the broad-scale features of predicted changes are in apparent agreement with the expected circulation changes. Accordingly, northern tropical areas may be expected to become wetter throughout the year. The summer rainfall region may experience wetter summers while wetter summer and drier winter conditions are expected for the winter rainfall region of the SW Cape. However, caution must be exercised in the interpretation of simulated precipitation changes over the subcontinenl due to the coarse spatial resolulion and simplistic parameterisation of precipitation mechanisms used in the models.

Introduction

General circulation model (GCM) simulations of global climatic change have important implications for regional climates (Gates et al., 1990; 1992). The reliability of regional simulations of climatic change depends largely on the ability of the models to simulate present conditions for a specific region accurately (Grotch and MacCracken, 1991; Karl et al., 1990; Mitchell et al., 1987; Portman et al., 1992). For Southern Africa, GCM simulations of possible future conditions have been presented previously (Tyson, 1990; 1991; 1993). Until recently, however, such predictions have not been supported by an assessment of the ability of the models to simulate present-day conditions for the region. Such an assessment of the present-climate performance of six early-generation equilibrium climate models for Southern Africa has recently been completed (Joubert, 1993; 1994), allowing for the development of more reliable scenarios of regional climatic change than was previously the case. Those models which were shown to simulate present-day surface air temperatures, mean sea level pressures and precipitation most accurately, will be used here to illustrate possible future conditions, given a doubling of the atmospheric carbon dioxide concentration.

Data and methods

The models considered here are all equilibrium climate models linked to mixed-layer slab oceans. In each case, the models are run to statistical equilibrium under present climate conditions, with current levels of atmospheric carbon dioxide (I x *CO2)*. Once this equilibrium has been established, the concentration of CO_2 is instantaneously doubled (2 x CO_2) and a new equilibrium is allowed to re-establish. Climatic change may then be estimated as the difference between the mean equilibrium 1 x CO_2 and 2 x CO_2 states. The selection of models for consideration of doubled CO_2 simulations is based on the assessment presented in Joubert (1994). For surface air temperature changes, the 1984 Goddard Institute of Space Studies (GISS) 9-level model (Hansen et al., 1983; 1984), the 198711 -level United Kingdom Meteorological Office (UKMO) model (Wilson and Mitchell, 1987) and the 1992 9-level Commonwealth Scientific and Industrial Research Organisation (CSIRO9) model (McGregor et al., 1993; Whetton et al., 1993) will be used. Only the CSIRO9 model will be considered for possible changes in mean sea level pressure. A range of models is considered for precipitation changes over the subcontinent. These are the GISS, UKMO, and CSfRO9 models, as well as the 1987 9-level Geophysical Fluid Dynamics Laboratory (GFDL) model (Manabe and Wetherald, 1987).

Received 23 March 1994; accepted in revisedform 27 June 1994.

Simulated data from general circulation models

Details of the various model experiments are given in Table I. There is considerable range in the spatial resolution of the four models. The UKMO model has the highest vertical resolution (11 levels) and the CSIRO9 simulation has the finest horizontal resolution (approximately 3.2° meridionally by 5.6° zonally). Several physical processes important for an accurate simulation of present-day Southern African climate and hence for reliable predictions of future climates, are simplistically treated (Joubert, 1994). *All* models are linked to a simple mixed-slab ocean with no ocean currents, although horizontal heat transport is prescribed in the GISS ocean. Ocean-atmosphere heat exchange in the GISS, UKMO and CSIRO9 models is constrained by the use of a Q-flux procedure which results in an accurate representation of present-day seasonally-varying sea-surface temperatures. However, this correction prevents ocean temperature and sea ice from responding in climatic change sensitivity (doubled *CO_2)* experiments, thereby excluding a crucial feedback mechanism (Washington and Meehl, 1991).

The parameterisation of convection at model grid points inevitably results in a poor simulation of the magnitude of observed precipitation over the subcontinent, due to the mismatching of scale between observed and simulated events (Gordon et al., 1992). Simulated changes in *total* rainfall over Southern Africa *must* therefore be interpreted with caution. Cloud optical properties are held constant in both the 1 x CO_2 and 2 x CO_2 runs, effectively preventing the models from adjusting cloud radiative forcing of temperature as a result of changes in radiation associated with