WATER RESEARCH COMMISSION

February 2016

The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Climate change

Radiative forcing of southern African climate change

A newly-completed Water Research Commission (WRC) study explored various forms of tropospheric and stratospheric radiative forcing on southern African variability and change.

Background

This WRC project and is associated final report is concerned with exploring the its effects of various forms of tropospheric and stratospheric radiative forcing (e.g. Antarctic stratospheric ozone, increasing CO_2 concentrations and time-varying aerosol forcings) on southern African climate variability and change.

Methodology

A large set of sensitivity tests, following the experimental design of the Atmospheric Model Intercomparison Project (AMIP) was performed for this purpose. An ensemble of projections of future climate change has also been analysed, to investigate the relative importance of enhanced CO_2 concentrations and recovering stratospheric ozone in forcing southern African climate during the 21st century.

The simulations of seasonal circulation anomalies are in general most skilful for the austral summer. This result provides some insight in the relatively high levels of skill reported in general for the prediction of summer rainfall totals over southern Africa at the seasonal time-scale – this skill stems from the underlying circulation fields being forecasted skilfully for summer.

The drastic reduction in skill that occurs in the autumn, winter and spring seasons over southern Africa (as demonstrated in this report) may be attributed at least partially to the seasonal northward-displaced westerlies, with its associated transient weather systems of which the variability is simulated less skilfully.

Another important contributing factor may be that ENSO related SST anomalies are generally the largest during the early summer, with important regional SST anomalies such as those associated with the South Indian Ocean subtropical dipole being the largest in the late summer. That is, the abilities of the tropical Pacific Ocean and regional oceans to force climate variability over southern Africa are reduced outside the austral summer. These arguments suggest that improvements in forecast skill may be extremely difficult to attain for the seasons of autumn, winter and spring.

The inclusion of time-varying stratospheric ozone concentrations improves the simulation skill of circulation variability over the Southern Ocean in spring and over southern Africa in summer. This result is consistent with dynamic circulation theory, according to which stratospheric forcing over Antarctica in spring has a pronounced mid-latitude response in summer.

Main results

This study is the first to demonstrate that this response actually reaches the subtropical latitudes of southern Africa. The inclusion of time-varying CO_2 concentrations offer some benefit for the simulation of summer-time inter-annual variability, particularly in the tropics.

The simulated changes in skill are, however, negative for most other seasons and regions. The prognostic treatment of aerosols is problematic in the model simulations for winter, and leads to decreases simulation skill over the southern African interior.

However, the use of prognostic aerosols improves the model to simulate inter-annual variability in spring and summer circulation, for most of the southern African region.

The analysis of simulated temperature trends for the various radiative forcing simulations has yielded an important result – the inclusion of time varying CO_2 concentrations is essential to realistically simulate the observed trends, even in the presence of observed SST forcing.

This result suggests that the local increased absorption of infra-red radiation through enhanced levels of CO_2 plays an important role in the strong temperature trends observed over southern Africa. Under low mitigation, and even under relatively high mitigation scenarios such as RCP4.5, the poleward displacement of the westerlies is projected to strengthen during the 21st century – despite the recovery of stratospheric ozone concentrations.

This large-scale hemispheric change in the circulation is contributing to the projected changes of rapidly rising surface temperatures over southern Africa in winter, and the robust projections of decreasing rainfall over the southwestern Cape. The maintained poleward displacement of the westerlies may also contribute to the occurrence of increased rainfall totals projected by some climate models over eastern South Africa, particularly during summer.

The CCAM simulations forced with time-varying ozone concentrations are able to reproduce the most important dynamic and thermodynamic features of the stratosphere and the troposphere.

The most important shortcoming in the simulations is the colder South Pole (compared to observations) and a persistent relatively weak meridional temperature gradient in the stratosphere, particularly for the summer months.

This systematic error prevents the full reversal of the stratospheric flow to occur. This might have implications for the simulation of stratosphere-troposphere coupling. The tropospheric circulation is simulated realistically in general. Forcing CCAM with time-varying ozone fields enables the model to successfully simulate the impact of ozone depletion.

All the well-known results from studies that have been conducted with chemistry-climate models with interactive stratospheric chemistry are reproduced here, including the pronounced southern displacement of the westerlies in summer under depleted stratospheric ozone.

Momentum fluxes demonstrate the impact that ozone depletion may have had on weather systems affecting South Africa. It appears to have shifted some of the weather systems eastward and southward, with enhanced easterly flow over South Africa in summer.

This may have contributed to the increasing trends in rainfall observed over parts of the summer rainfall region of South Africa, particularly in summer.

Further reading:
To obtain the report, *Radiative forcing of southern African climate variability and change* (**WRC Report No. 2163/1/15**), contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.