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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

Developing defensible regional climate change projections

A completed Water Research Commission (WRC) study aimed to answer the question 'How do I assess the regional climate change information for my sector/location/decision/policy?'

Background

In many respects the above question is a problem of ethics; the challenges only exist because of the choices humankind has made, and our future depends on the choices we will make – choices that are now, in part, predicated on projected climate change.

At the regional scale our choices are complicated by the large uncertainties in the degree and rate of change and our incomplete knowledge of how human and physical systems will respond. The central problem is the pressure to operationalise what is effectively incomplete and ongoing research by the global scientific community.

The approach adopted considers the historical changes from observed data, changes in the driving circulation patterns, the projected changes at the regional scale from the Global Circulation Models (GCMs), and from the information downscaled from the GCMs. At the core is a need to provide information that is credible, defensible, and ultimately actionable.

The final report of this project covers each avenue of potential sources of information on regional change, and concludes with a framework for integrating these in a sector-specific context to inform decision-makers and policy. This is developed as a transferable and scalable approach to support decision-makers and policy development.

The four foundations

1. Observed historical changes

The exploration of historical observations of weather and climate serves a dual role in the context of developing defensible regional projections for a particular region. Firstly, observations and the analysis of these observations enhance our understanding of the nature of a variable climate as expressed in a particular region.

Secondly, it is often very useful for decision-makers to know if the climate has exhibited a consistent long-term change over the past decades as this can provide some insight into historical trends of impacts such as water scarcity, crop, yields, dam levels etc.

Station selection for this analysis draws from a suite of 4 034 rainfall observing stations across South Africa extending from as early as 1 850 through to the end of 2012. Stations for the analysis were selected by finding all stations that had less than 10% of values missing during the period 1960 to the end of 2012. This resulted in 784 stations in the subset.

There can be very complex patterns of trends through the year for a particular location, and to evaluate the seasonal nature of change, the analysis aggregates daily statistics up to monthly statistics and all trend analysis is done on individual calendar months through time.

The focus is on monthly total rainfall, rain days, rain days with more than 10 mm of rain, rain days with more than 20 mm of rain, and maximum daily rainfall in a month. The results are presented as monthly maps of station trends. For each month, only those stations that exhibit a statistically significant trend at the 90% level are displayed.

A large number of results present a nuanced picture of historical picture of historical change, and a close examination is required in the context of the user's vulnerability. A number of important features stand out. Most notably is the strong drying trend across the central and northeast of the country in April which appears to relate to an earlier cessation to the summer rainfall regime.

Also of interest is the indication of increasing rainfall across the centre of the country (slightly to the west) in the summer months (December to February). December, in particular, shows an increase in rainfall across the Free State, suggesting a stronger start to the rainfall season.

Many of the trends are statistically significant, suggesting a response to an underlying process, presumably global climate change, though other drivers should also be considered. The observed trends are complex, varying from positive to negative and significant or not significant at the same location through different months of the year.

2. Modes of variability in climate models

The regional messages derived from models are contingent on the model's skill in simulating the driving circulation processes. The objective of this step is to explore the relevant attributes of the GCMs from the perspective of circulation – the skilful scale of GCMs.

Two approaches are explored: the model's ability to reproduce the large-scale processes of relevance to southern Africa, and an examination of model performance of the regional scale circulation patterns.

Results show that the CMIP5 models have some skill in simulating the leading mode of global variability: ENSO. Most of the models tend to show dry conditions (although weaker in magnitude) over southern Africa during strong El Niños, and the newer versions of the GCMs are starting to produce marginally more realistic results.

The regional circulation patterns are credible across models, although the biases between models and the diversity of frequency of regional circulation models highlight the critical importance of not using any single one model.

The information from circulation changes lies in assessing the results across models, and taking one model in isolation is as likely to lead to an erroneous conclusion as it is to provide some partial value.

3. Assessing uncertainty in the climate projections

The uncertainty associated with climate modelling is one of the leading problems in climate change studies. Uncertainty arises from the inherent stochastic and chaotic behaviour of the climate system, from structural errors of models, from simplifications in the modelling system, from lack of scientific knowledge, and a host of other secondary factors.

A number of experimental and traditional methods are explored. Analyses are motivated by the need to provide quantitative estimates of projection uncertainty for South Africa consistent with state-of-the-art methods and concepts.

In particular, the project team addresses a comprehensive description of uncertainties, explores two relatively new avenues of assessing GCM performance, analyses uncertainties involved in statistical downscaling of GCM output to higher resolution, local scale level, and evaluates climate projection uncertainty using traditional methods.

Approaches are introduced to analyse multi-method ensembles and the consistency in time and space between the spread of the method-specific ensembles to explore its implication to the interpretation of climate change signal derived from individual methods. Three dominant 'spaces' are identified where uncertainty in projections of future climate arise; the socio-economic space, climate system space, and model space. Each of these is discussed.

Quantitative assessment is explored through a new experimental procedure to examine the climate system high-dimensional space to characterise the local-scale variance in context of the larger determining state of the atmosphere. This indicates a strong value potential for this approach, but will need significant further work to develop to the point of robustness.

Following this the role of small-scale processes in contributing to uncertainty of rainfall projections is examined. The uncertainty arising from this probabilistic nature of local response to large-scale synoptic forcing is relatively large and this uncertainty is only partly sampled by the ensembles.

Because of its magnitude, it may be important for determination of significance of the change signal, and the interpretation of ensemble results in terms of change signal consistency and significance against the natural variability.

Finally, the uncertainty of projections is assessed through more traditional approaches by analysing ensemble spread from multi-model, multi-method datasets. The degree of agreement between methods (ensembles) varies between variables and seasons.

For summer rainfall there is a broad consistency and for summer temperatures there is relatively little difference in tendency and magnitude in each of the ensembles. For winter temperatures the ensemble differences are more pronounced.

At the sub-continental scale, the multi-model, multi-method data allows for a straightforward derivation of climate change messages with varying degrees of confidence dependent on location, season and variable. There is more confidence in temperature projections in the coastal regions than in the continental interior. For rainfall, there are indications of higher confidence in low rainfall regions.

In summary, the analysis of agreement/differences in ensemble spread and tendency from three methods has potential to contribute to confidence statements about local and regional climate change messages.

4. Downscaled projections

This section in the final report focuses on downscaled data, which is the next source of climate data to be included in the conceptual framework for integrating regional information. Downscaling seeks to add finer resolution information to GCM output and is seen as the only viable approach to achieve regional scale information consistent with the global and hemispheric forcing.

Two sources of downscaling are considered. First is that of the Coordinated Regional Downscaling Experiment (CORDEX) operating under the Working Group on Regional Climate Change (WGRC) of the World Climate Research Programme (WCRP). Second is statistical downscaling, which is based on the established method from CSAG.

A clear message of warning over South Africa is seen in the raw GCM output as well as both downscaling methods. Warming is projected to be most intense over the drier parts of the interior, while less intense along the coast.

Some measure of disagreement in the exact spatial distribution and magnitude of warming is evident between GCMs and between different downscaling products, but does not undermine the basic message.

Projected changes in precipitation into the future are less confident than for temperature. GCMs disagree on the sign of change over the region with some projecting strong wetting while others projecting strong drying.
The range projected by the two downscaling methods is narrower than that of the driving GCMs. However, there is still strong disagreement in the sign of change and placement of areas of wetting or drying. The ensemble mean change also disagrees between the two downscaling methods which widens the spread of projected changes.

Framework of integration

In any climate data source there is both implied and real information, and the final robustness of any message is subject to the interpretation of the scientists and users. Context is highly relevant, and a product can be robust at larger scales but questionable at small scales.

The information required by users is highly dependent on the application, the relevant scales in time and space, and the user's risk exposure. The final section of the report thus demonstrates how the climate information may be a) distilled to key messages), and b) integrated with the sector and/or place-based context of any application.

The approach is based on the idea of progressive layering of information to find the intersection of individual elements of robust information, and so to lead to a conclusion that is defensible and informative to the user. One begins by ignoring the climate information to first identify the points of vulnerability in a system, and then consider whether and how these points of system vulnerability are sensitive to climate factors.

With an initial assessment of systems vulnerabilities, independent of the climate factors, one is in a position to layer on additional climate information drawing from the understanding of each of the foundation sources of information. At this point one has an emerging picture of the system vulnerabilities alongside what one can say with reasonable robustness about the past changes in the climate system.

In the final stage, one looks for the intersection of sensitivities in the sector/place with the identified strong messages of change. This approach allows for quick identification of how critical points of vulnerability that are sensitive to climate forcing relate to the defensible climate change understanding.

In some respects the process is relatively intuitive. However, articulating vulnerabilities in terms of thresholds is difficult, and often not attempted. Further, the propensity of users to treat data as information means the distillation of the multiple lines of evidence is commonly not undertaken, which leads to subsequent confusion when climate data introduces contradictions.

Example of application

The developed framework was applied in two contexts. First through a series of workshops, which engaged stakeholders in the Berg River municipality in the Western Cape. Second, the evolving ideas were tested in a separate project action with five African cities.

In each case the activities began with examining the non-climate stressors and key sector/place sensitivities and vulnerabilities independent of climate change. Following this the four avenues of climate information were examined, and the robust messages that could be drawn were then identified.

Last, the climate messages, as a function of scale and time, were assessed against the sector/place sensitivities and vulnerabilities to evaluate what can be said about the impact of climate change with some confidence, in order to inform the adaptation and decision options.

It is apparent from the experiences that the conceptual approach presents a powerful co-exploration paradigm that productively departs from the linear supply chain mentality. Of particular note is how the climate scientists learned from, and were greatly sensitised by, engaging the sector participants, and vice versa. This mutual exchange of understanding was a significant factor to finding defensible and rational messages for action.

The activities clearly indicate that it is possible to identify robust points of intersection between the multiple and disparate data sources – arguably the leading contribution to maladaptation in the decision-maker's sphere of activities.

Further reading:
To order the report, ***Development of defensible regional climate change projections for adaptation and policy*** (**Report No. 2061/1/14**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.