10 Can We Predict Decadal Changes in Southern Hemisphere Climate?

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INTRODUCTION

Our awareness and understanding of decadal and longer-term changes in climate have grown in recent years (e.g. droughts lasting many years with no clear links with ENSO, rising temperatures over our land and seas). But what can we say about how Australia's climate might unfold in the future? Questions like this can now be tackled with growing confidence using computer-based mathematical models of the Earth's climate.

Here we examine decadal variability in the BMRC (Bureau of Meteorology Research Centre, Australia) climate model (Power *et al*., 1998). This model simulates the coupled atmosphere/ocean/land/sea-ice system. A century long simulation of the model climate together with a series of *sensitivity experiments* will be used to quantify the *predictability* (i.e. degree to which something can be predicted) of naturally occurring decadal changes in the Southern Ocean and the South Atlantic.

We will see that a large fraction of the modelled decadal variability in surface temperature over southern Australia, southern Africa and New Zealand, associated with oceanic changes, seems to be predictable. It will be interesting to see if this new hypothesis is supported by analyses of other models and data.

RESULTS

Figures 10.1–10.3 indicate that there is a link between variability in the deep ocean in the South Atlantic, the sea-surface temperature (SST) in the Southern Ocean and surface temperature over land in the Southern Hemisphere. We begin our analysis of this chain of association in the South Atlantic. Figure 10.1 shows the northward current in the South Atlantic in the BMRC CGCM at two different depths: 2 km and 400 m. Note how they tend to be out of phase on decadal time scales, so that when flow at 400 m into the Atlantic is high, outflow at 2 km is also high. It is interesting to note that variations in these flows are closely linked to changes in SST in the Southern Ocean further south (Fig. 10.2). When the inflow is large the surface temperature over the Southern Ocean at similar longitudes is reduced.

The variability in SST over the Southern Ocean seen in Fig. 10.2 evolves very slowly, with anomalies lasting for well over a decade. The anomalies are communicated further east and can be seen in the southern Indian Ocean and over the Southern Ocean south of the Indian Ocean about four years later (Fig. 10.3a). Variability in SST over the southern Indian Ocean on decadal time-scales is in turn closely linked to surface temperature variability in southern Africa, southern Australia and New Zealand (Fig. 10.3b–d).

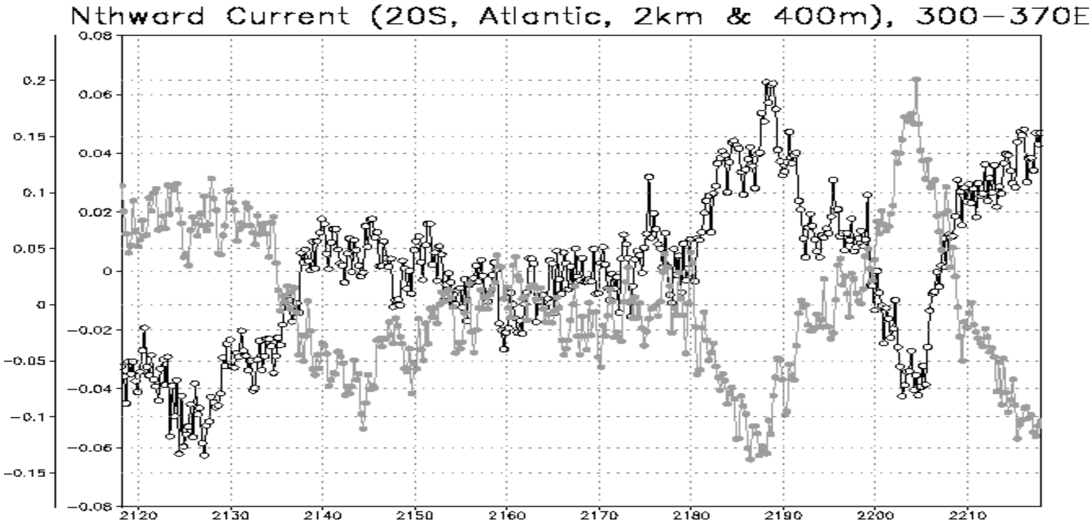

Fig. 10.1 *The northward current in the South Atlantic in the BMRC CGCM (Power et al. 1998) at two different depths: 2 km (open circles) and 400 m (grey, closed circles). Note how they tend to be out of phase on decadal time scales. When inflow at 400 m into the Atlantic is high, outflow at 2 km is also high.*

In summary when naturally generated long-lived wobbles occur in the sub-surface ocean over the South Atlantic, climate over Southern Hemisphere land is affected about four years later.

Sensitivity experiments

The long time scale associated with the variability discussed so far would suggest that it is partially predictable on decadal time scales. In order to test this we conducted a number of sensitivity experiments for oceanic inflow in the South Atlantic. For each starting point chosen we re-ran the model after giving it a small nudge. Highly chaotic systems are typically profoundly influenced by even the tiniest of nudges. If the variability is predictable then you would not expect the nudge to have a profound influence on the resulting evolution for the period of interest (i.e. a decade in this paper). Here we see that the inflow is highly predictable on decadal time-scales. So while chaos is present, it has only a minor influence on the decadal evolution of the conveyor belt.

CONCLUDING REMARKS

The ubiquitous presence of chaos in our climate system almost certainly sets limits on how accurately we will ever be able to predict changes in Australia, South Africa or New Zealand climate, no matter how advanced our understanding, observational networks and technology become. Nevertheless, our results suggest that we have not yet reached these limits and that exciting avenues for pursuing better predictions may lie ahead. Whether or not the predictable variability evident in this preliminary investigation has a genuine counterpart in nature remains to be seen. So perhaps the main point to note here is that climate models are improving and our confidence in

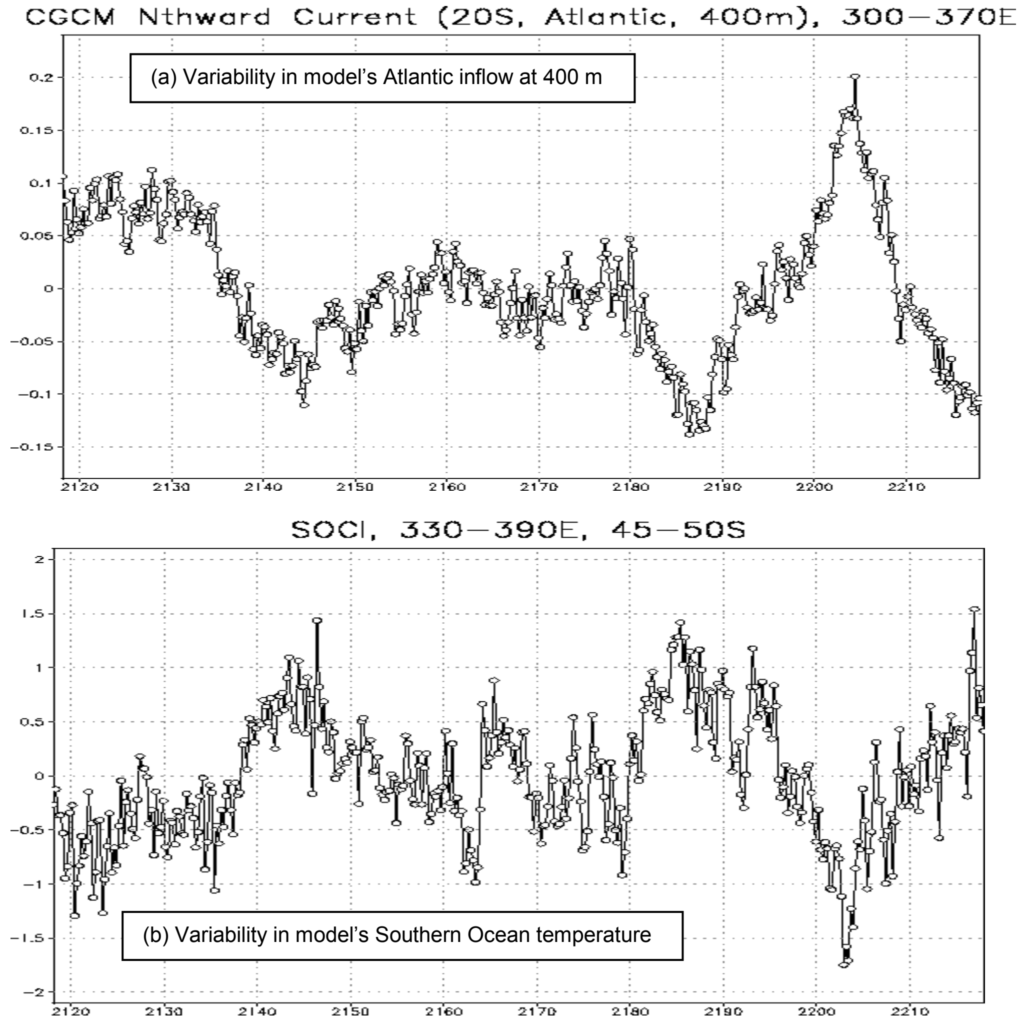

Fig. 10.2 *Time series of the outflow from the South Atlantic (a), with sea-surface temperature over the Southern Ocean at 330–390E and 45–50S (b). The two appear to be closely linked.*

their ability to simulate variability is growing and we can now begin to address important questions like those raised in the title of this paper. Confidence will increase further when similar signals are detected in a large number of climate models and where the modelled variability is shown to be consistent with observational variability. Future work will centre on both these issues.

Finally note that in this paper we have restricted attention to the predictability of variability arising from naturally occurring instabilities that exist in the ocean/atmosphere/sea-ice system. Things like variability in solar output and intermittent volcanic activity have been omitted. Furthermore while anthropogenic influences like global warming and ozone depletion have been omitted in this study, they are likely to provide unwanted but nevertheless important additional sources of decadal predictability. For example, it is probably more likely than not that the coming *decade*

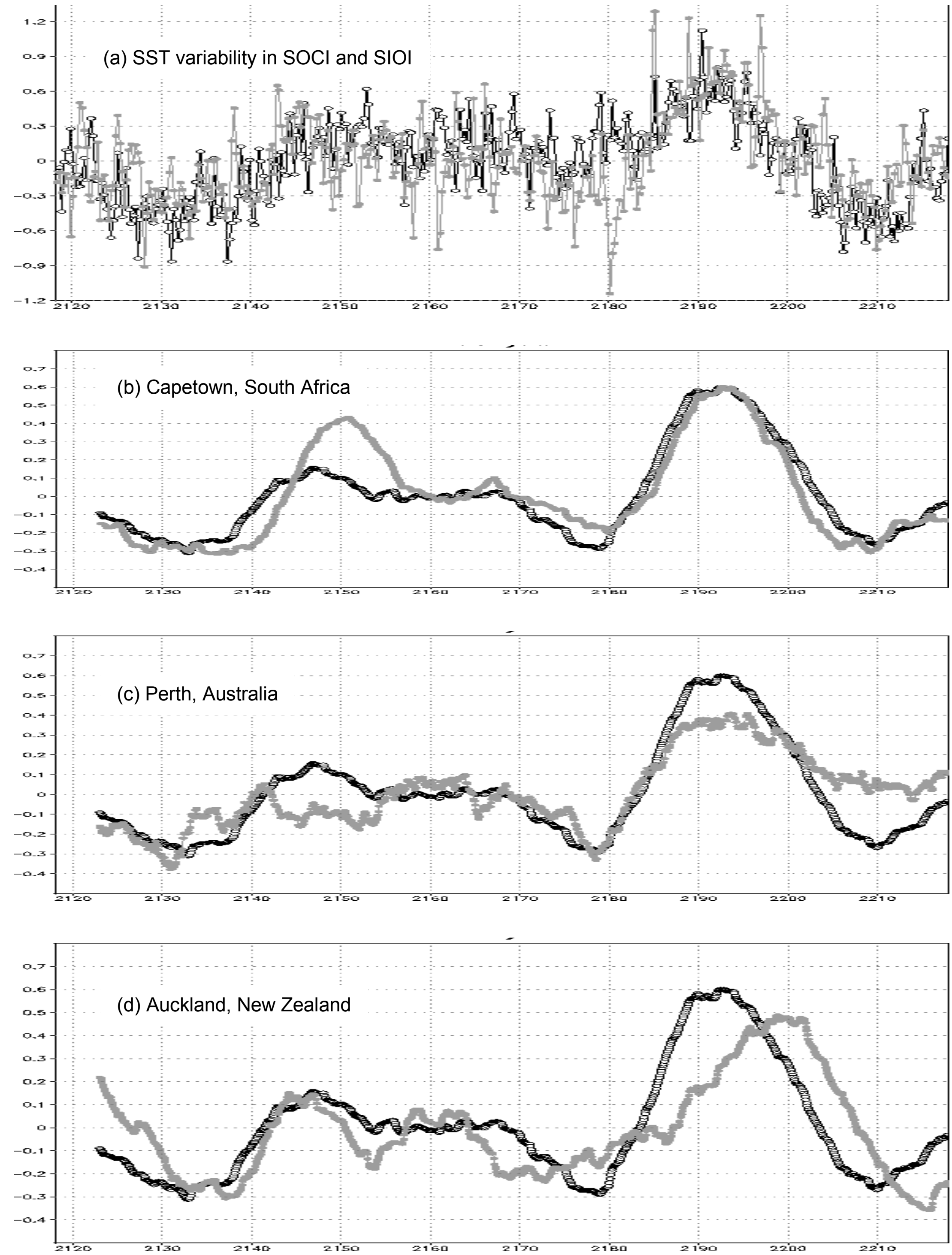

***Fig. 10.3** See opposite for full caption with an explanation of time series.*

***Fig. 10.3** (opposite) Time series showing an association between (a) SST variability in the Southern Ocean south of the Indian Ocean (SOCI, open circles) and the southern Indian Ocean (SIOI, grey, closed circles). The decadal component of SIOI is depicted as the dark line in (b)–(d), along with the decadal component of surface air temperature variability in the (b) Capetown, (c) Perth and (d) Auckland, regions (grey lines).*

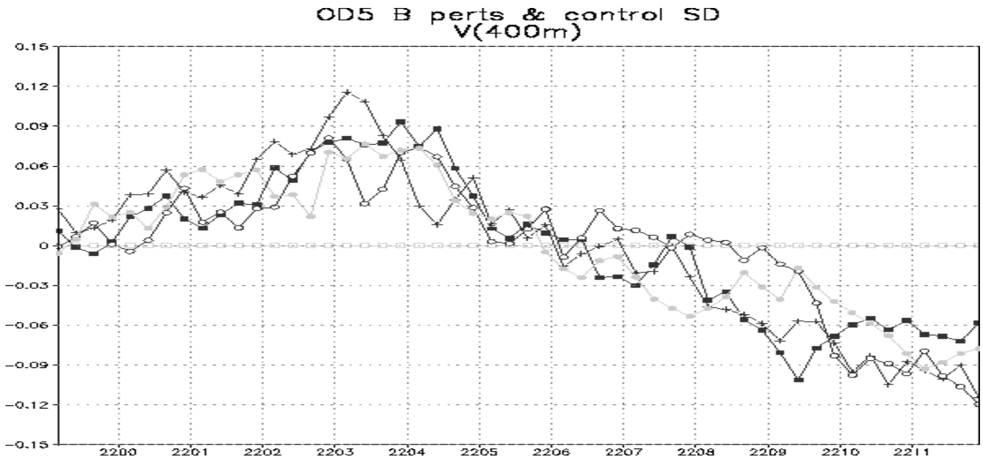

***Fig. 10.4** Sensitivity experiments for inflow in the South Atlantic. Clearly there are features of the ocean that are highly predictable on decadal time scales*

will be warmer in Australia than its counterpart in the last century. So a comprehensive assessment of decadal climate predictability will therefore include analysis of both naturally occurring and anthropogenic sources of variability.

Acknowledgements

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References

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