

# **A brief history of the numerical modelling of weather and climate at The University of Melbourne**

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The purpose of this review is to provide a brief overview of the numerical modelling of weather and climate system activities which have been conducted at The University of Melbourne. As befitting our academic environment and our responsibility in the training of quality and well-rounded scientists the range of activities is very broad, and only a glimpse of this range can be presented here.

## **Ice caps and glacial cycles**

One of the early topics of numerical modelling in the group was associated with the modelling of the climate and cryospheric response to Milankovitch orbital forcing, and the extent to which the periodic glaciations of the late Quaternary could be simulated. The modelling showed that if the appropriate feedbacks were included (e.g., CO<sub>2</sub> oceanic drawdown in glacial times, bedrock depression) these cycles could be reproduced. This work was also associated with more detailed modelling of the Antarctic ice sheet, and specifically directed to the mechanisms by which ice sheets periodically surge and retreat. Among the published works on these topics are those of Budd and McInnes (1974), Budd (1975), Budd and Smith (1981), Budd et al. (1984) and Budd and Rayner (1990).

## **Data assimilation and numerical weather prediction**

In the late 1960s the work of Charney and others had led to the concept and process we now understand as 'data assimilation'. In the 1970s it was held by many that the process of 'data insertion' would only give reliable results in grid-point models, as significant problems were envisaged in insertion into (non-local) spectral models. The first assimilation investigations with global spectral models (Simmonds 1978) completed in collaboration with GFDL showed that the structure of these models presented no fundamental difficulties to the technique.

Over the years a number of results have been produced of relevance to numerical weather prediction. The concentration of sea ice has significant impacts on the fluxes of heat and moisture between the surface and the atmosphere, and hence on the development and behaviour of cyclonic systems. Watkins and Simmonds (1995) quantified the extent to which changes in sea ice concentration can influence short-range forecasts over the SH.

In the past there was vigorous debate as to the relative importance of synoptic systems and katabatic outflow in inducing the very strong winds found on most of coastal Antarctica. The study of Murphy and Simmonds (1993) showed that the events are associated with strong katabatic and strong gradient flow operating together.

Investigations were been conducted to explore of the value of ensemble forecasting, and these led to insights as to the optimum methods of perturbing initial conditions (Noone and Simmonds 1998a).

## **Statistical significance, model 'spin-up', and effects of surface forcings**

In the early days of climate modelling and conducting sensitivity tests little attention was given to the statistical significance of results, or indeed to allowing a climate model to 'spin-up'. Some of our work in the early 1980s contributed to the design of appropriate significance testing (Simmonds 1981) and a quantification of the time scales on which The University of Melbourne atmospheric GCM 'forgot' its initial conditions (Simmonds 1985)

A significant body of work has been directed to understanding and quantifying the effect of changing surface conditions by making use of 'sensitivity' studies in the GCM. Early work on this topic addressed the consequences of the zonal asymmetry of global SSTs (Simmonds et al. 1989), and the association between regional SST and Australian rainfall SST (Simmonds 1990, Simmonds and Rocha 1991).

Other inquiries undertaken with the GCM highlighted the important role played by soil moisture in the climate system, and the extent to which this important parameter provides a mechanism for 'memory', with implications for its use in seasonal forecasting (Simmonds and Lynch 1992, Simmonds and Hope 1998). Wardle and Smith (2004) modified the model surface albedo, and found that Australian temperature and

precipitation trends over the last century could be ‘explained’, in part, by the response to adjusted reflectivities.

## **Influences of topography and of the atmosphere on the ocean**

The topographic effects of the Andes and Antarctica on SH circulation and synoptic activity have been explored by Walsh (1994) and Walsh et al. (2000).

A number of modelling studies have explored the details of atmosphere-ocean momentum exchange in general circulation models, including those of Bye and Wolff (1999, 2001).

## **Snow, clouds and sea ice**

An important component of our modelling effort has been directed toward devising more physically-based parameterization schemes for various processes, and using these to understand better how the atmospheric climate system responds to these features. We confine ourselves to mentioning some of our studies addressing the prediction of snow on the ground (Walland and Simmonds 1996, 1997) and of clouds (Argete and Simmonds 1996).

The cryosphere (and in particular sea ice) plays a very important interactive role in the climate system. Simmonds and Budd (1990, 1991) designed a method to represent the dramatic effect that open regions in the pack ice zone have on the vertical fluxes of heat and moisture. Further research developed an ice prediction model, which was used in a range of sensitivity studies (Wu et al. 1996, 1997).

## **The ‘Southern Annular Mode’ and the ‘semiannual oscillation’**

The principal component of variability in the SH is the ‘Southern Annular Mode’. Its temporal spectrum is very broad and much research has been devoted to understanding its characteristics. Rashid and Simmonds (2004, 2005) have constructed numerical models which cast light on the eddy-zonal flow feedbacks associated with this mode and the reasons for its persistence.

Another dramatic feature of SH is the ‘semiannual oscillation’. Numerical experiments have been performed to determine the sensitivity of this feature to changes in surface boundary conditions (Walland and Simmonds 1998) and explored its variability in a long integration in the GFDL coupled model (Simmonds and Walland 1998).

## **Ocean modelling**

Part of our ocean modelling activities have been directed at developing orthogonal and curvilinear grids which have advantageous properties, and applying these in regions such as the South Indian and Arctic oceans (e.g., Murray 1996, Murray and Reason 2001a, b). More conventional ocean models have also been used to explore the mechanisms of variability in the SH (Reason et al. 1996, Reason and Lutjeharms 2000, Reason 2000).

## **‘Nudging’**

While designing numerical experiments to ascertain the model response to changes in *external* forcings is relatively straightforward, the picture is not so clear when one wishes to change parameters which are themselves dependent model variables. The technique of ‘nudging’ has been used in many creative ways to effect this. For example, Simmonds et al. (1992) were able to differentiate the thermodynamic and dynamic influences at work when attempting to understand the influence of Indian Ocean temperatures on the Australian precipitation regime. Similarly, Murphy et al. (2002) explored the role of baroclinicity in the SH by ‘nudging’ tropospheric temperature gradients in their simulations.

## **Trace gas budgets and Isotopes**

The comprehension of the budgets of greenhouse trace gases is obviously of central importance in compiling scenarios for future climate change. Among our contributions to these issues may be mentioned the investigations of Law et al. (1992), Law and Simmonds (1996) and Butler et al. (2004).

Isotopes (both stable and unstable) have proved of immense value in diagnosing past climates, and increasingly are being used to understand present climate and its variability (such as the age of deep oceanic waters, the atmosphere hydrologic budget, and atmospheric transport paths). Noone and Simmonds (1998b, 2002a, b, 2004) Noone and Simmonds (2004) have incorporated a sophisticated stable water isotope scheme into The University of Melbourne model, and have used it in a number of revealing experiments. Brown and

Simmonds (2004) have used the scheme to highlight the dangers inherent in the traditional interpretation of isotopic records.

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