Pan evaporation in 20th Century global climate simulations: model implementation and results for Australia

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Measurements of pan evaporation have been used for several decades in agricultural science as an estimate of the "evaporative demand" of the atmosphere. Recent interest in pan evaporation has been provoked by an apparent paradox. On the one hand, a warmer climate associated with the anthropogenic greenhouse effect is expected to have a generally more active hydrological cycle (Folland et al. 2001). On the other hand, widespread decreases of pan evaporation, averaging 2-4 mm per year per year, were observed over several decades up to about 1990 (e.g., Peterson et al. 1995). While most of these observations have been in the Northern Hemisphere, recent analyses of data from Australia (Roderick and Farquhar 2004) and New Zealand (Roderick and Farquhar 2005) have shown similar results. The observed reductions in pan evaporation in the Northern Hemisphere are broadly consistent with observed reductions in solar radiation at the Earth's surface in the period up to 1990 (Stanhill and Cohen 2001, Roderick and Farquhar 2002). Some of this "solar dimming" is simulated by Global Climate Models (GCMs) that include increases in anthropogenic aerosols (Liepert et al. 2004), suggesting that anthropogenic aerosols probably contributed to the reductions in pan evaporation, at least in the Northern Hemisphere. However, current indications are that existing GCMs are able to capture less than half of the observed solar dimming, even when aerosols are included with plausible assumptions. The results from Australia and New Zealand are even more puzzling than those from the Northern Hemisphere, because it seems unlikely that anthropogenic aerosols have contributed substantially to climate change in the relatively pristine Southern Hemisphere.

Motivated in part by these considerations, we have developed a simple model of evaporation from a "US Class A pan", as a tool for analysis of simulations from the CSIRO GCM. The pan evaporation model is slightly modified from earlier work by Linacre (1994), whose "Penpan equation" was essentially a version of Penman's (1948) equation with parameter values appropriate for a Class A pan. The inputs to the Penpan model are monthly mean fields saved from the CSIRO GCM, so it is easy to make minor adjustments to the Penpan model without rerunning the GCM.

We refer to the version of the GCM we use as the Mk3a model. It is a low-resolution (spectral R21) version that has been enhanced relative to the standard CSIRO Mk3 model (Gordon et al. 2002) by the inclusion of a comprehensive aerosol module and new radiation routines that can treat aerosols as well as non-CO2 greenhouse gases (Grant et al. 1999, Chou and Lee 2005). The aerosol scheme treats the tropospheric sulfur cycle in some detail (Rotstayn and Lohmann 2002) and has recently been updated with established schemes that treat carbonaceous aerosols (Cooke et al. 1999), mineral dust (Ginoux et al. 2004), sea salt (O'Dowd et al. 1997) and volcanic aerosol (Sato et al. 1993). With Joyce Penner and her colleagues at University of

Michigan, we have included parameterizations of the shortwave optical properties of the above aerosol types (paper in preparation), as well as a new data set that estimates the historical emissions of carbonaceous aerosol from fossil-fuel and biomass burning (Ito and Penner 2005). Historical emissions of sulfur are updated and extended from Smith et al. (2001). The model also includes treatments of both the first and second indirect aerosol effects (Rotstayn and Liu 2003, Rotstayn and Liu 2005).

The inclusion of detailed aerosol treatments make the CSIRO Mk3a model an attractive tool for investigating unresolved issues related to pan evaporation and solar dimming and their implications for our understanding of climate change. The lower horizontal resolution of the Mk3a model means that we have to use an older version of the Cox-Bryan ocean model (Hirst et al 2000), since the ocean model used in the standard Mk3 GCM has only been configured for use at high resolution (spectral T63). The coarse horizontal resolution and the limitations of the ocean model have some implications (such as an inadequately resolved El Nino), but an important advantage of the low-resolution model is that multiple runs can be performed relatively quickly.

In the presentation, the first author will describe and present some results from the model. Figure 1 shows the modelled annual pan evaporation over Australia, averaged over the period 1971 to 2000. Comparison with the observations collated by Roderick and Farquhar (2004) shows that the model broadly captures the magnitude and spatial pattern of pan evaporation over Australia. The modelled trends in Australian pan evaporation will also be discussed, in light of the observed decrease that was described by Roderick and Farquhar.

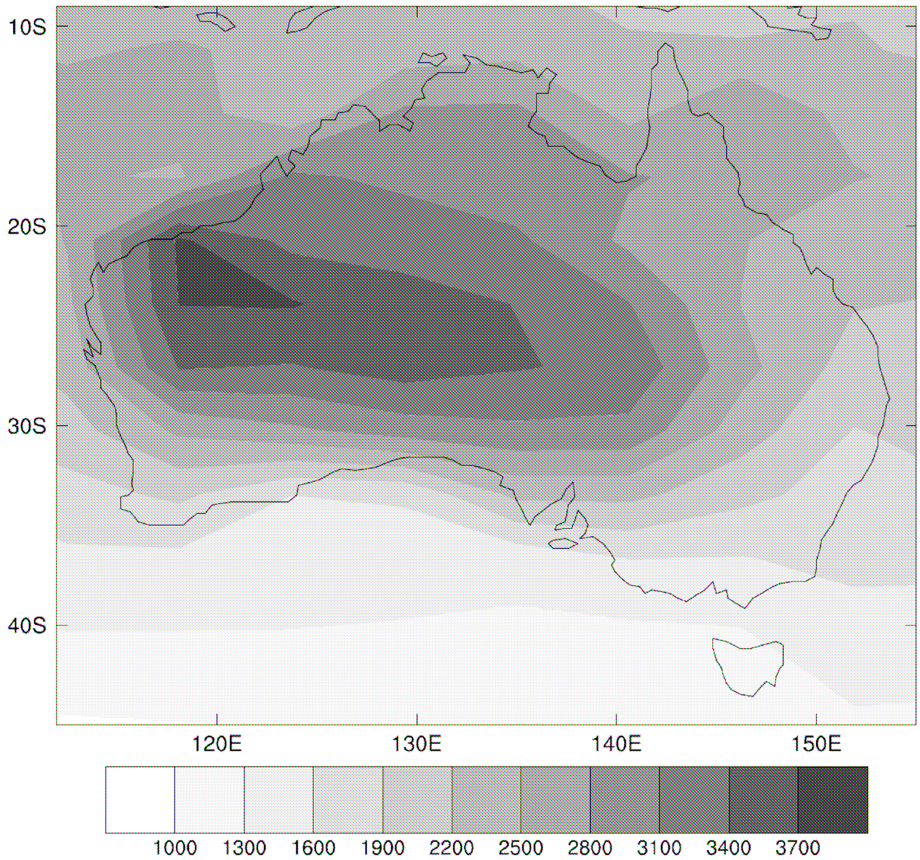

Figure 1: Pan evaporation over Australia in mm per annum, averaged over the period 1971-2000 from an ensemble of eight runs of the CSIRO Mk3a model with “all forcings” (greenhouse gases, ozone, anthropogenic aerosols, solar variations, volcanic eruptions).

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