1 Introduction

The transient response of climate to a gradual increase in atmospheric CO_2 has been studied and reported by four groups so far (IPCC, 1992). These studies were performed at the Geophysical Fluid Dynamics Laboratory (GFDL; Stouffer *et al.*, 1989; Manabe *et al.*, 1991; Manabe *et al.*, 1992; Delworth *et al.*, 1993), the National Center for Atmospheric Research (NCAR; Washington and Meehl, 1989; Meehl *et al.*, 1993), the Meteorological Office (UKMO; Murphy, 1992, 1995a,b) and the Max Planck Institute for Meteorology (MPI; Cubasch *et al.*, 1992). None of these models have sufficiently fine horizontal resolution of the ocean to simulate El Niño phenomena, although Neelin (1991) has shown that coarse-grid coupled models do simulate an unstable coupled mode that contributes to some of the ENSO signal. There are debates on how El Niño phenomena change under global warming. The GFDL group has shown that the amplitudes of sea surface temperature (SST) anomalies during ENSO-like events in a CO_2-warmed climate are slightly reduced compared to those in control run (Knutson and Manabe, 1994). The MPI group also speculates that El Niño would be less active under the warming process (Lunkeit *et al.*, 1993), while the NCAR group showed that there would be no significant change in SST variability with increased CO_2 but that there would be enhanced precipitation variability (Meehl *et al.*, 1993). In contrast, the UKMO group showed no significant changes in the equatorial SST variability between their transient and control simulations (Tett, 1994). However, these models have not successfully simulated the whole cycle of El Niño phenomena. Unless we perform simulations of the transient response to gradual increases in CO_2 with a model which simulates them more realistically than those run so far, no convincing conclusion can be reached.

Neither sea ice thickness nor its distribution is well simulated by some models used for transient response studies. In one model, sea ice thickness in some areas of the Antarctic Ocean in September is more than 3 m (Manabe *et al.*, 1992). However, observations show that the thickness of the sea ice in the Antarctic ocean in austral midwinter is 40-60 cm (Wadhams *et al.*, 1987). In another model, sea ice in the Antarctic ocean has almost disappeared, even in September (Murphy, 1992). If a model fails to simulate either thickness or distribution of sea ice or both of them well, then it is