1. Introduction

Climate models are the most important tools available today for enhancing our scientific understanding of the great complexity of the climate system and for projection of future climate change. The Meteorological Research Institute (MRI) of Japan has been developing climate models for several decades. The first atmospheric general circulation model (AGCM), referred to as MRI-GCM-I (Tokioka et al., 1984; Kitoh et al., 1995), was coupled to a global ocean general circulation model (OGCM) (Nagai et al., 1992) to create MRI's first-generation atmosphere–ocean coupled global climate model (MRI-CGCM1). Tokioka et al. (1995) used MRI-CGCM1 to conduct a global warming experiment in which they examined transient responses to a cumulative increase in the atmospheric carbon dioxide (CO_2) concentration of 1%/year. The results of this experiment contributed to the 2nd Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 1996). A global spectral AGCM developed from the operational weather prediction model of the Japan Meteorological Agency (JMA) with a horizontal resolution of ~280 km was used to replace the earlier AGCM grid (4° × 5° horizontal resolution) in MRI-CGCM1. The resulting model became MRI's second-generation CGCM, MRI-CGCM2 (Yukimoto et al., 2001). Several climate change projection experiments (Noda et al., 2001) based on scenarios forced by greenhouse gases and sulfate aerosol concentrations were conducted with MRI-CGCM2. An improved version of the MRI-CGCM2 (MRI-CGCM2.3; Yukimoto et al., 2006) was used in the 3rd phase of the Coupled Model Intercomparison Project (CMIP3) of the World Climate Research Programme, which compared 23 models from institutions around the world. In this intercomparison, MRI-CGCM2.3 was found to exhibit excellent climate reproducibility, which led to its being a significant contributor to the 4th Assessment Report of the IPCC (IPCC-AR4; IPCC, 2007).

Climate change projection results from each generation of MRI's CGCM have been downscaled with providing boundary conditions to regional climate models (e.g., Sasaki et al., 2006; Takayabu et al., 2007), which, when utilized for detailed projections of climate change, have performed well in simulating the climate around Japan.

The projections of future climate change in IPCC-AR4 were based on numerous experiments with more than 20 CGCMs that yielded results with quantitative confidence levels. As a result, IPCC-AR4 contained a stronger conclusion than the previous assessment reports. That stronger statement was possible because many of the participating models were able to account for the observed climate change in the twentieth century, which suggests that these models can predict future climate change with higher confidence than before. The range of the uncertainties in the projections, however, remained as large as in the 3rd Assessment Report (IPCC, 2001), and the main source of the uncertainty in climate sensitivity was caused by cloud feedback. Bony and Dufresne (2005) suggested that the different responses of low clouds over subtropical oceans to global warming among the simulations was the most important factor causing the sensitivity spread among the models. The uncertainty related to aerosols radiative forcing was also a large uncertainty factor. In particular, there are many questions about the modeling of the indirect effects of aerosols, which must take into account sophisticated cloud microphysics (involving a large computational cost). In addition, climate models are now expected to represent important interactions between climate and atmospheric chemistry, for instance, ozone changes associated with climate change and anthropogenic trace gases such as chlorofluorocarbons (CFCs), and volcanic impacts on climate.

Also important is the accurate quantitative estimation of feedback processes between the carbon cycle and climate change. IPCC-AR4 estimated this feedback by using earth system models of intermediate complexity, which are simplified, low-resolution models. A more realistic earth system model (ESM) based on a CGCM that incorporates the full complexity of physical processes, with sufficiently high resolution, and sophisticated carbon cycle process simulation is required to achieve a more accurate quantitative estimation of this feedback.

A major theme of the next IPCC Assessment Report, IPCC-AR5 (which will have CMIP5 as its scientific basis, and is expected to appear in 2013), in addition to the long-term projections (~2100 and later) as presented in past IPCC reports, is near-term prediction, targeting climate change 20 to 30 years in the future and including the prediction of decadal variability as an initial value problem. More regionally precise information on climate change in the near future is required for near-term projection, and climate models must be able to accurately reproduce the decadal to multi-decadal variability observed in the latter half of the twentieth century, as well as the present-day mean climate.

Earth system models for IPCC-AR5 have been developed at several climate modeling centers. An ESM has also been developed at MRI under the special research program "Comprehensive Projection of Climate Change around Japan due to Global Warming." In conjunction with the ESM development, a global AGCM has been developed at MRI in collaboration with JMA and the Advanced Earth Science and Technology Organization. This AGCM has performed well in reproducing the overall atmospheric fields (Mizuta et al., 2006). A very high resolution (20-km mesh) version of the AGCM has produced many excellent present and future climate simulation results with regard to, for example, typhoons (Oouchi et al., 2006), the Baiu (Kusunoki et al., 2006), regional climate, and extreme events. This report describes the ESM that MRI has developed, called MRI-ESM1, which incorporates these successful results, in preparation for the CMIP5 experiments that will contribute to IPCC-AR5.