

# Improvements and Reductions in Systematic Errors Associated with Clouds in the MRI Climate Model

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The previous version of a climate model of MRI, MRI-CGCM3 (Yukimoto et al. 2012), which was used for CMIP5, had various systematic errors associated with clouds. In the updated version of our climate model, MRI-ESM2, some of such errors are reduced and representations of clouds and aerosol indirect effects are improved. The main improvements are as follows:

(i). There was a significant shortwave radiative flux bias over the Southern Ocean in the old version as is the case for many climate models. However, the bias was considerably reduced mainly due to an introduction of a new stratocumulus parameterization (Kawai 2013). (ii). Ice phase clouds were excessive and super-cooled liquid clouds were deficient over the Southern Ocean, compared with CALIPSO satellite data, in the old model. On the other hand, super-cooled liquid clouds were increased in the new version, which is consistent with the satellite data, and the change also contributed to the reduction in shortwave radiation bias over the area. (iii). Vertical structures of low clouds off Peru were unrealistic in the old version. However, they were significantly improved by a modified treatment of interaction between stratocumulus and shallow convections. (iv). An increase in the vertical resolution from L48 to L80 contributed to solve the problem of geometrically too thick low-level clouds that have too high albedo. (v). A bug fix related to prognostic equations of number concentrations of cloud particles solved the problem of extremely large number concentrations of cloud particles. (vi). Aerosol mode radii were modified based on recent observations, resulting in appropriate number concentrations of cloud particles. (vii). Treatment of cloud ice fall was improved based on Kawai (2005), though the old method can cause unphysical calculation of cloud ice content.

These improvements were achieved thanks to valuable information from many model intercomparison studies and projects.

## Reference

- Kawai, H., 2013: Improvement of a Stratocumulus Scheme for Mid-latitude Marine Low Clouds. *WGNE Blue Book*, **43**, 4.03-4.04.
- Kawai, H., 2005: Improvement of a Cloud Ice Fall Scheme in GCM. *WGNE Blue Book*, **35**, 4.11-4.12.