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Design and Development of a Planetary Atmospheric General Circulation Model

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A general circulation model (GCM) is a numerical model that calculates global scale atmospheric circulation used in meteorology, geophysical fluid dynamics, and planetary atmospheric science. Significance of knowledge of diversity of planetary climate is increasing due to discovery of extrasolar planets. Then significance of research of diversity of planetary climate with GCM is increasing too. However, validity of calculation results that is checked with observational data heretofore is difficult to check in planetary atmospheres because observational data of planetary atmospheres are very little compared with the earth. There is an intercomparison of results of multi models with different complexity as one of the methods of consideration of validation of calculation results of planetary atmospheres. But the intercomparison of multi models with different governing equations and program structures requires a large amount of labor. We think that an ideal form of models for intercomparison equips following three features. First, methods of calculation, analysis and visualization, edit of programs are uniformed in all models. Secondly, correspondences of calculating formulas that are executed in models to mathematical formulas are easily comprehensible. Thirdly, physical processes such as radiation and subgrid-scale cumulus and turbulence can be changed or edited easily.

We are trying to produce the models for intercomparison by improvements of program techniques. A concrete goal is "planetary atmospheric hierarchical models" that are developed and maintained with four same systems, that are data I/O mechanism, program documentation system, programming style, and program structure. Before now, the models and related programs have been designing and implementing (Enhanced version of RDoc Fortran 90/95 parser, Morikawa et al., Tenki 2007; Gtool5 Library, Morikawa et al., JPGU 2009). In this study, applicability of techniques that are considered and improved until now for GCM is confirmed. As a result, feasibility study of planetary atmospheric hierarchical models is advanced. GCM in this study is named "dcpam5 (Dennou Club Planetary Atmospheric Model version 5)". First, Gtool5 library for data I/O, and enhanced version of RDoc Fortran 90/95 parser for program documentation is introduced to dcpam5. Secondly, a programming style in which array-valued functions are utilized proposed by SPMODEL: A Series of Hierarchical Spectral Models for Geophysical Fluid Dynamics (Takehiro et al., 2006) is introduced for enhancement of the mathematical expressions of source codes. Lastly, a program structure that is based on a general circulation model AGCM5 (SWAMP Project, 1998), and improved in two points of replacement with Fortran 90 and packaging all dynamical/physical processes into modules is introduced for enhancement of detachable of each process.

Validity of introduced techniques is checked by fundamental experiments with the GCM. It is confirmed that the programming techniques about data I/O and program documentation can be shared from huge and complex models such as GCM to more simple models. As a result, it is indicated that methods of analysis of calculation results and edit of programs can be uniformed in multi models with different complexity. On the other hand, it is indicated that there are some issues that are investigation of effect of programming style on execution speed, and establishment of interfaces of physical values between dynamical/physical processes.

Keywords: atmospheric general circulation model, planetary atmospheres,
hierarchical numerical models, dcpam5 (Dennou Club Planetary Atmospheric Model version 5),
Gtool5 Fortran 90/95 Library, Enhanced version of RDoc Fortran 90/95 parser