Development of the Physics Library and its application to ASUCA

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1 Introduction

Achieving efficient operations of numerical models on scalar multi-core architecture is a challenging issue in light of the rapid expansion of the market share for massive scalar computers in the supercomputer world. In order to overcome the problems anticipated in this regard, we have been developing a new nonhydrostatic dynamical core named ASUCA (Ishida et al. 2009, 2010). Flux-form fully compressible governing equations are adopted and discretized using the finite volume method to secure mass conservation. The flux limiter function proposed by Koren (1993) is employed to satisfy monotonicity and avoid numerical oscillations. The third-order Runge-Kutta scheme is adopted for the time integration of the system. A study by Ishida et al. (2010) involving a number of idealized experiments for dynamics showed that ASUCA exhibits high levels of performance. It has also been confirmed that mass conservation in the domain is well satisfied.

In order to utilize the new model as a practical forecast model, it is essential to implement physical processes. Although simply porting the physical processes of the current operational nonhydrostatc mesoscale model (JMA-NHM, Saito et al. 2007) may seem the easiest way to achieve this, maintaining and developing both codes would involve a huge cost burden. The Physics Library, currently under development, represents a trial effort to realize the sharing code for physical processes not only between ASUCA and JMA-NHM but also among various other models. The initiative is expected to facilitate efficient development of physical processes and promote related collaboration.

This paper describes the basic design of the Physics Library and outlines its purposes and current specifications. ASUCA is the first model for the library to be installed into practical models. Preliminary results of ASUCA with physical processes are also discussed here.

2 Physics Library

Computer libraries generally contain collections of subroutines and functions commonly used by various applications. Likewise, the Physics Library is intending to serve as a repository for various subroutines related to physical processes with unified coding and interface rules, and allows them to be shared among various forecast models. Physical processes in the library are implemented as vertical one-dimensional models aiming at low memory usage to improve cache efficiency, which is absolutely crucial for scalar computers. This simple one dimensional implementation is expected to make the development of physical processes more efficient.

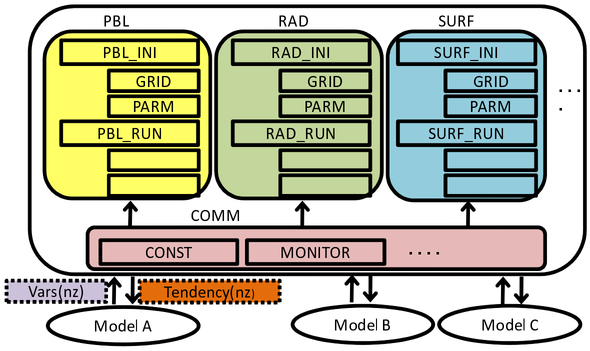

Fig. 1: A schematic representation of the Physics Library and its various components (`COMM`, `PBL`, `RAD`, `SURF` etc). Each component is basically independent and can contain one or more schemes. The library receives inputs (`Vars(nz)`) from models and returns tendencies (`Tendency(nz)`) to them.

The fundamental role of physical processes is to evaluate temporal tendency of prognostic variables brought by subgrid transport related to convection, turbulence and gravity waves as well as other effects that the governing equations of dynamics cannot describe (radiation, condensation, etc.). In consideration of the role played by physical processes, the library returns tendencies of prognostic variables without changing the variables themselves and other inputs provided by users. When users pass one dimensional arrays of physical quantities to the library, they can receive tendencies of prognostic variables, as shown in Fig. 1.

A number of idealized test programs following the configurations of international intercomparison projects for physical processes (GABLS2, GABLS3, EUROCS, GCSS-ARM, TRMM-LBA, etc.) are also included in the package of the library. With the test programs, one can evaluate performance of physical processes and compare two or more schemes contained in the library each other. The programs can also be referred to as sample code to show how each subroutine in the library is used. The test programs are expected to help users develop and evaluate physical processes and to facilitate the installation of subroutines contained in the library to practical models.

Documentation on the interfaces of subroutines in the library are quite important to show the usage of the library. However, interface modification is often not accompanied by documentation updates especially if the documents and code are separated. To secure simultaneous updating, documentation on the interfaces is included with code in the form of special

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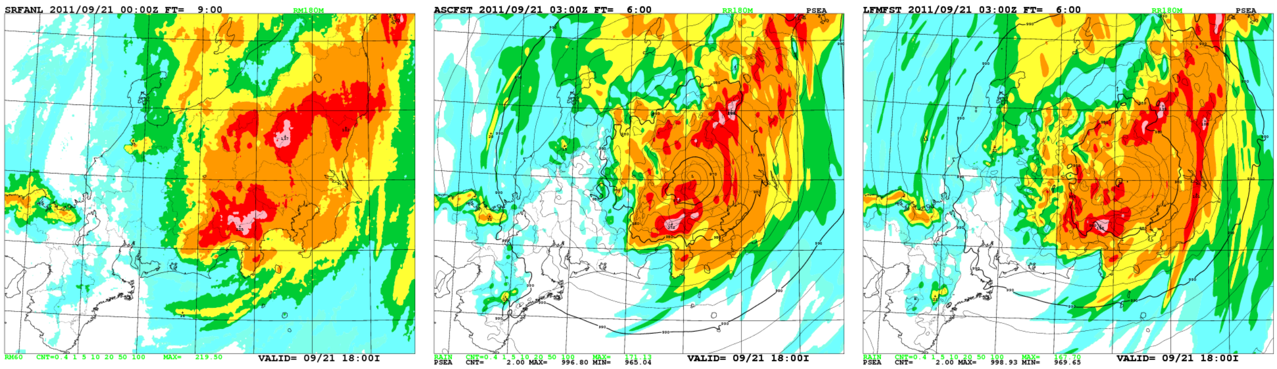

Fig. 2: Simulation results initialized for 03 UTC on 21 September, 2011. MSLP and 3-hour accumulated precipitation at 6 hours from the initial time are displayed with the corresponding precipitation observations. Left: observation (precipitation only), center: ASUCA, right: JMA-NHM.

comment lines. A tool can be used to extract this inline information and convert it to useful formats such as HTML and LaTeX.

Currently, physical schemes implemented in JMA-NHM have been just ported into the library. We are going to collect more schemes from mesoscale weather forecast models to global climate models to make it a true library resource. Intercomparison of schemes is one of the basic developments of physical processes, and will be facilitated by the library once it is populated with various schemes.

Although the library was originally intended to support the sharing of code for physical processes, it also supports the more efficient development of physical processes which requires detailed and extensive knowledge of physics and meteorology. The resource also serves as a basis of "seamless" model development of which importance is often claimed recently.

3 Application of "Physics Library" to ASUCA

Once most physical processes equivalent to those of the current operational mesoscale model were implemented in the Physics Library, attempts were made to install physical processes using it. It took just a week for a developer of ASUCA (who is not a developer of the library) to implement boundary layer, radiation, surface and microphysics onto ASUCA referring to the documentation on interfaces of the library. To check correct implementation, configurations identical to those of the idealized experiments included as sample and test environments in the library were also built in ASUCA. It has been confirmed that ASUCA with the physical processes produced results almost identical to those of the library's test environment, indicating that the physical processes were successfully installed as the developer of the library intended. The simple, organized, and documented interfaces of the library are expected to help model developers implement and try various physics schemes.

4 An example of the simulation of ASUCA with physical processes

The successful installation of physical processes using the Physics Library as described above allows comparison between ASUCA and other practical models including the current operational model (JMA-NHM). Figure 2 shows an example of such comparison with reference to the corresponding observation. In this case, it can be seen that both models produce good forecasts with results similar to those of actual observation.

5 Conclusion and future plans

ASUCA can now be compared with other practical models because physical processes have been implemented as appropriate. From the early stages of development of ASUCA, we consider that sharing code of physical processes among models as the Physics Library is essential for efficient progress.

As far as the preliminary evaluation, ASUCA with physical processes produces results similar to those of the current operational mesoscale model JMA-NHM in regards to the distribution of precipitation brought by a typhoon. Further evaluation of ASUCA is now being carried out to allow comparison of its statistical aspects to those of JMA-NHM.

The successful use of the Physics Library with ASUCA represents its first application to practical models. To cement its status as a fundamental tool supporting development and collaboration related to physical processes, it is necessary to collect more schemes and implement more test cases.

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