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Implementation of spherical harmonic transform models on massively parallel computers

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Spherical harmonic transform method (SHTM) is widely used in numerical weather predictions, climate simulations and planetary dynamo simulations. The SHTM is a spectral method based on spherical harmonic transformations consisting of the Fourier transform and the Legendre transform. This method has good accuracy and, especially in planetary dynamo simulations, can easily treat boundary conditions for a magnetic field at a spherical interface between a conductor and an insulator. However, the SHTM is less suitable for large-scale simulations on parallel computers than methods such as the finite difference method, because the SHTM needs ALL-TO-ALL-type global communications between processor elements and the computational complexity of the Legendre transformation is $O(N^3)$, rather than $O(N^2)$ like in the finite difference method, where N is a degree of freedom in one dimension on a spherical surface. We need a careful consideration for implementation of the SHTM on large-scale simulation models.

One of the largest-scale simulation models that uses the SHTM is AFES, which is an atmospheric general circulation model highly optimized for the Earth Simulator. AFES achieved 26.58 TFlops, which is 64.9 % of the theoretical peak performance of the Earth Simulator (Shingu et al., 2002). The Earth Simulator is a vector computer and was the world fastest machine in 2002-2004, according to a ranking of computers Top 500 (http://www.top500.org/). However, most of the computers listed in recent Top 500 are scalar computers, and the computers listed in the top 10 have more than 10,000 - 100,000 processor cores. It can be said that the main stream of supercomputers has shifted from expensive vector computers to massively parallel scalar computers.

It is a stiff problem for the SHTM to achieve high performance and make the most of its computational advantages on massively parallel supercomputers. In this study, we consider this problem and discuss the possibilities of large-scale and high-speed calculations of the Legendre transformation.