Performance Measurement of Eulerian Kinetic Code on the Xeon Phi KNL

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Eulerian Kinetic (Vlasov) Simulations for Space Plasma Studies

Basic equations for collisionless space plasma:
- Maxwell equations (for electromagnetic wave propagations)
\[ \nabla \times E = -\frac{\partial B}{\partial t} \quad \nabla \times B = \mu_0 J - \frac{1}{c^2} \nabla E \]
Computational load less than 0.1%
- Collisionless Boltzmann equation with electromagnetic field (known as Vlasov equation for charged particle motions)
\[ \frac{\partial f}{\partial t} + \mathbf{v} \cdot \nabla f = 0 \]
\[ \frac{\partial f}{\partial x} + \mathbf{E} \cdot \nabla f = 0 \]
\[ \frac{\partial f}{\partial v_x} + \frac{q}{m} (\mathbf{v} \times \mathbf{B}) \cdot \nabla f = 0 \]
Operator splitting into three equations
- Advection in position by \( \mathbf{v} \)
- Advection in velocity by \( \mathbf{E} \)
- Rotation by \( \mathbf{B} \)

Examples
Current Layer

System Description
- Xeon Phi 7250 (68 cores, 16GB MCDRAM)
- 96GB DDR4
- Intel Compiler Ver.17.0.1
  - Option: -ipo -ip -O3 -xMIC-AVX512
- Number of grids: 40*40*40*128*64*2
  (~28GB > MCDRAM)
- Elapsed time for 5 time steps is measured
- Memory mode: Flat, Cache
- Cluster mode: All2All, Hemisphere, Quadrant, SNC-2, SNC-4
  ⇒ Memory and Cluster modes are selected from BIOS
- Default environmental variables

40³ ~ 4GB
40⁶ ~ 160GB

Performance Measurements
- 64 cores are used (4 cores are free)
- Number of processes (Np) are changed by fixing the total load
  \[ 64 = \text{Np} \times \text{Nt} \]
  (number of threads)
- Flat-MPI (Np=64) is slowest
- Hybrid parallelism with 4 and 16 processes is fastest
- Cache mode is ~1.5 times faster than Flat mode
- Small difference among the performance of All2All, Hemisphere, and Quadrant
- SNC-2 and SNC-4 have a tendency of performance similar to Hemisphere/Quadrant
- However, performance becomes worse with some number of threads
  - 1 process - 64 threads for SNC-2(#5)
  - 1 process - 64 threads for SNC-4(#6)
  - 8 and 16 processes for SNC-4(#6)
  ⇒ the performance becomes further worse with KMP_AFFINITY=compact environmental variable!!

Strong Scaling with Np = 4
- Scales up to 17 threads
- Hyper Threads (HT) is effective with 32, 64, and 68 threads
- Performance loss with HT for Flat model(#1)
- Performance loss with 32 threads for SNC-2(#5)

Strong Scaling with Np = 16
- Scales up to 4 threads
- HT is effective with 8, 16, and 17 threads
- Performance loss with HT for Flat model(#1)
- Performance loss with 8 threads for SNC-2(#5)
- Performance loss with 4 and 8 threads for SNC-4(#6)