The state-of-the-art remapping process for the Korean Integrated Model (KIM)

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SCREEN CAPTURE WELCOME

1 Background

- This study introduces the remapping system of the state-of-the-art Numerical Weather Prediction (NWP) model, the Korean Integrated Model (KIM), developed by the Korea Institute of Atmospheric Prediction Systems (KIAPS).
- KIM employs the quasi-uniform and pole singularity-free spherical geometry, a cubed-sphere grid, essentially requiring the remapping in the pre-/post-process.
- The remapping process of KIM consists of two parts:
  [1] Figuring out reference points from source (SRC) grid points and weights at each reference point, which can be calculated prior to the remapping process
  [2] Calculating the values at destination (DST) points by multiplying the values at reference points and appropriate weights, which can be improved by optimizing and parallelizing
- Various strategies to improve the remapping system; using and pruning remap matrix, optimizing and parallelizing calculations are suggested.

2 Remap Matrix

Grid System & Remapping Algorithms

- Cubed-sphere Grid (Fig. 1)
  - quasi-uniform
  - pole singularity-free
- Remapping Algorithms (Table 1)

Table 1. Remapping algorithms provided by KIM

Name	Explain
Nearest	copying from the nearest SRC point
Bilinear	the 2-D linear interpolation from the nearest 4 points sieging the DST point
Lagrange polynomial	a polynomial interpolating the SRC points in an element containing the DST point
Dominant	the mode value of the SRC points in Voronoi surface
Cell-average	the average value of the SRC points in Voronoi surface

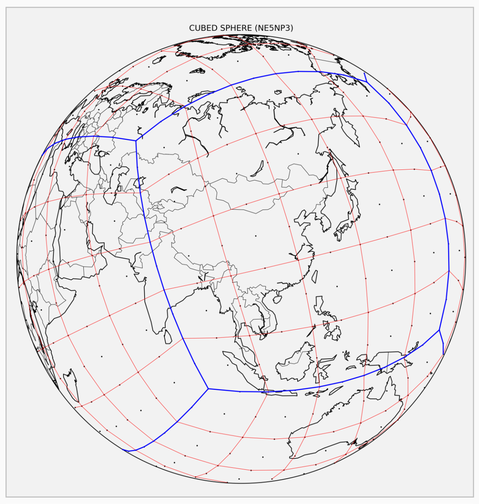

Fig 1. Example of cubed-sphere grid system (resolution: ne5np3 ≈ 1,000km)

- Alternative Bilinear Method (Fig.2; Kim et al., 2019)
  - The conventional bilinear method can be easily implemented in a rectangular-shaped grid system, however, it is challenging to use in a grid with a non-uniform distribution
  - KIM provides the alternative bilinear method supporting arbitrary geometrical configuration of source points

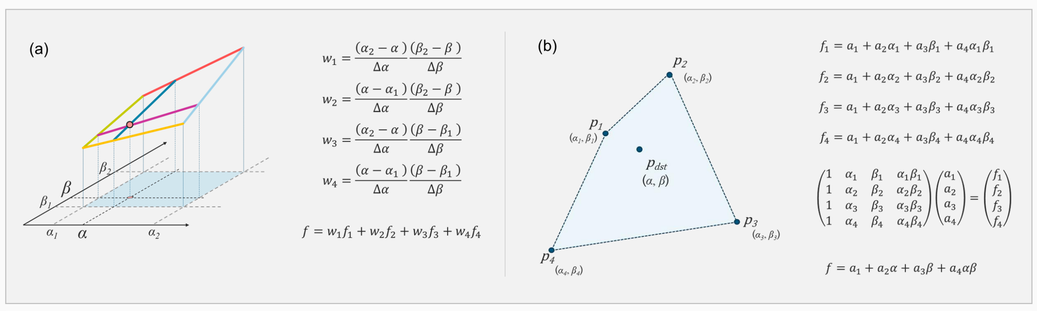

Fig 2. Comparison of (a) the conventional bilinear method and (b) the alternative bilinear method

Remapping Process using Remap Matrix

- Remap Matrix
  - A remap calculation of remapping algorithms provided by KIM can be represented as a matrix calculation (Fig. 3 blue square).
  - The remap matrix is unique for the pair of SRC-DST grid systems (Fig. 3 green square)
    → calculate a remap matrix prior to remap once or store a remap matrix often used
  - Pruning: Compressing a remap matrix instead of using a full matrix
    → only store address of reference points and their weights (Fig. 3 dark yellow cells)

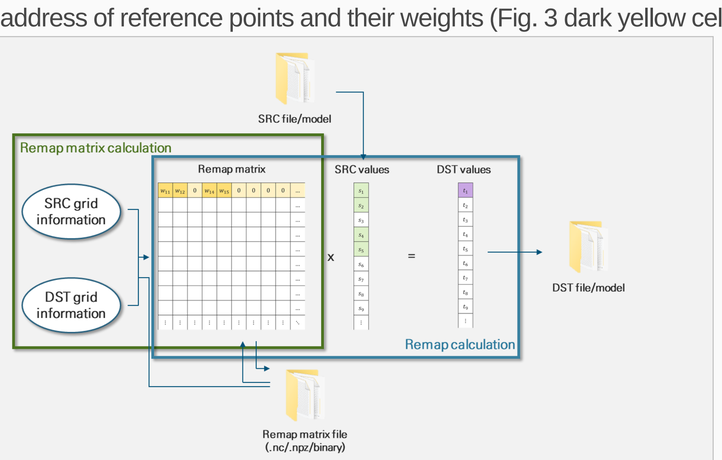

Fig 3. Remapping process of KIM

3 Optimization & Parallelization

Environment & Experiment Setting

- System: guru/maru (Korean 5th Supercomputer) pre-/post-system
  - 120 nodes, 534TF
  - processor: Cascade Lake 2.9Hz 24 cores (two slots in a node), memory: 69,120 GB
- Resolution: ne360np3 (cubed-sphere, 12km) → 2880x1440 regular (lat-lon grid)
- Thread parallelization with OpenMP
- 40 experiments for each

Results

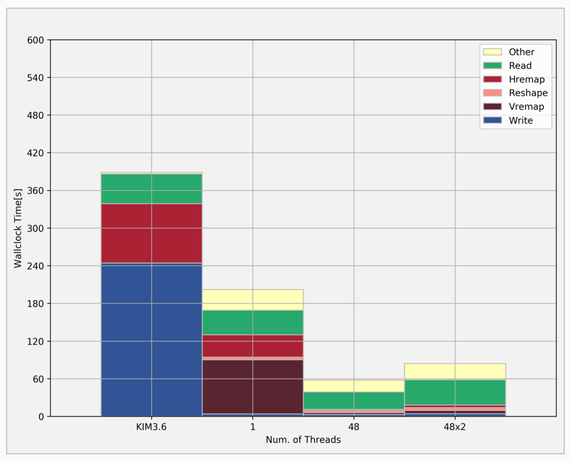

Fig 4. Wallclock time of each work process for remapping depending on the KIM version and thread size

- The post-system of the KIM3.7 based on Fortran has replaced the Python-based system in KIM3.6.
- Single thread exp. shows that the speed of total post-process has improved up to 1.8 times compared to the original system through optimization.
- Full thread exp. (48 threads) shows 3.5 times faster than the optimized system (single thread), and 15 times faster when considering a remap calculation only.
- Hyper-threading technique is not so helpful.

Table 2. Average (Minimum) wallclock time for remapping cubed-sphere to lat-lon grid

Avg. (Min.) Wallclock Time [s]	KIM3.6	Thread 1 (Optimized)	Thread48 (Parallelized)	Thread46x2 (Hyper-threading)
Total	388.7 (297.0)	201.8 (184.1)	57.7 (46.2)	84.2 (70.0)
Read	47.5 (35.8)	38.9 (19.6)	27.7 (16.5)	40.3 (32.7)
H. Remap	94.7 (89.0)	35.8 (32.3)	1.7 (1.5)	4.2 (1.6)
V. Remap		86.2 (77.3)	3.1 (2.5)	5.3 (2.3)
Reshape		4.2 (3.3)	3.4 (3.3)	4.4 (3.4)
Write	244.2 (154.7)	3.9 (2.8)	2.8 (2.7)	4.1 (2.8)

- Calculation speed saturates to about ten times that of a single thread (Fig. 5 green line).
- At the 12 km resolution, the speed improves about four times faster (Fig. 5 red line).
- The improvement is up to 6 times at lower resolutions where the I/O impacts less on speed.

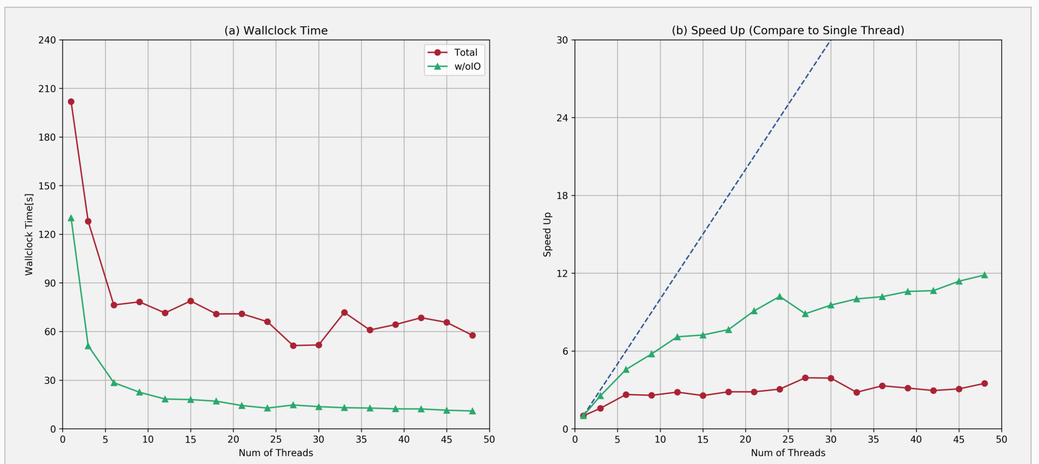

Fig 5. (a) Wallclock time and (b) speed up from a single thread while red lines with circle markers represent the total process and green lines with triangle markers represent the remap calculation only

4 Summary & Conclusions

- KIM provides various remapping algorithms including the alternative bilinear method which treats a non-uniform grid system.
- Remap matrix allows us to save time by performing some calculations in advance.
- Optimization and parallelization help a remapping speed to improve up to 3-4 times faster (12 times without I/O), but the speed is saturated when separating threads more than 12.
- These results will be reflected in the operational NWP system of the Korea Meteorological Administration.

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