Parallel second order conservative remapping on the sphere

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1. Introduction

We present an implementation of a conservative 1st/2nd interpolation between arbitrary spherical meshes with convex elements, in particular meshes used by IFS model: structured grids such as octahedral or reduced Gaussian grids of IFS, quasi-structured grids such as ORCA of NEMO and FESOM2, or fully unstructured grids. For his work shares a lot in common with an earlier work in [1]. Here, we used a different approach for typical ingredients of remapping process, namely that of spherical polygon intersections (Sutherland-Hodgman) and that of a fast search of potential intersectors (kD-tree) for a given polygon. For these two we rely on available tools of our in-house numerical library for weather simulations – Atlas. On top of the traditional cell-to-cell remapping, we extended the remapping to allow staggering of data – data can be either in cell centres or cell vertices on a source mesh, and, independently of the source data localisation, remapped to the cell centres or to the cell vertices of target mesh.

2. Staggering

We support remapping of staggered data. Data points can be located in the cell centres **or** in the nodes/vertices of a given mesh (again, structured or unstructured). This is achieved through construction of sub-quadrilaterals as in Fig. 1. around each node as in [2]. Staggering effects are best seen in Fig. 2. for the 1st order remap from CubedSphere grid CS-LFR-8 to a much higher resolution O256. The imprinting of a lower resolution into O256 is clearly visible in case of the 1st order. The advantage of the 2nd order is substantial for source meshes of lower resolution to the target mesh as seen in Fig. 5.

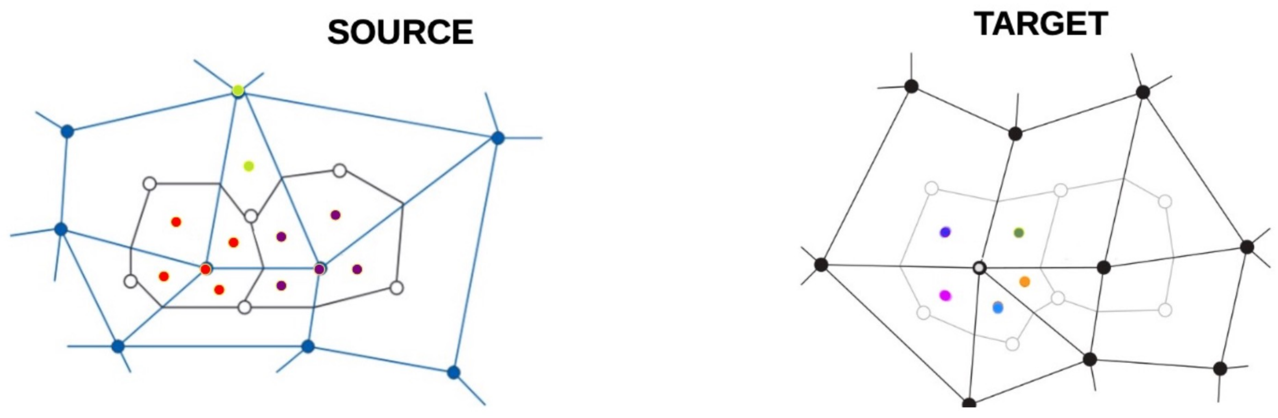

Fig 1. The idea of delegating conservative remapping from nodes to polygons on a source mesh and back on a target mesh. Based on [2].

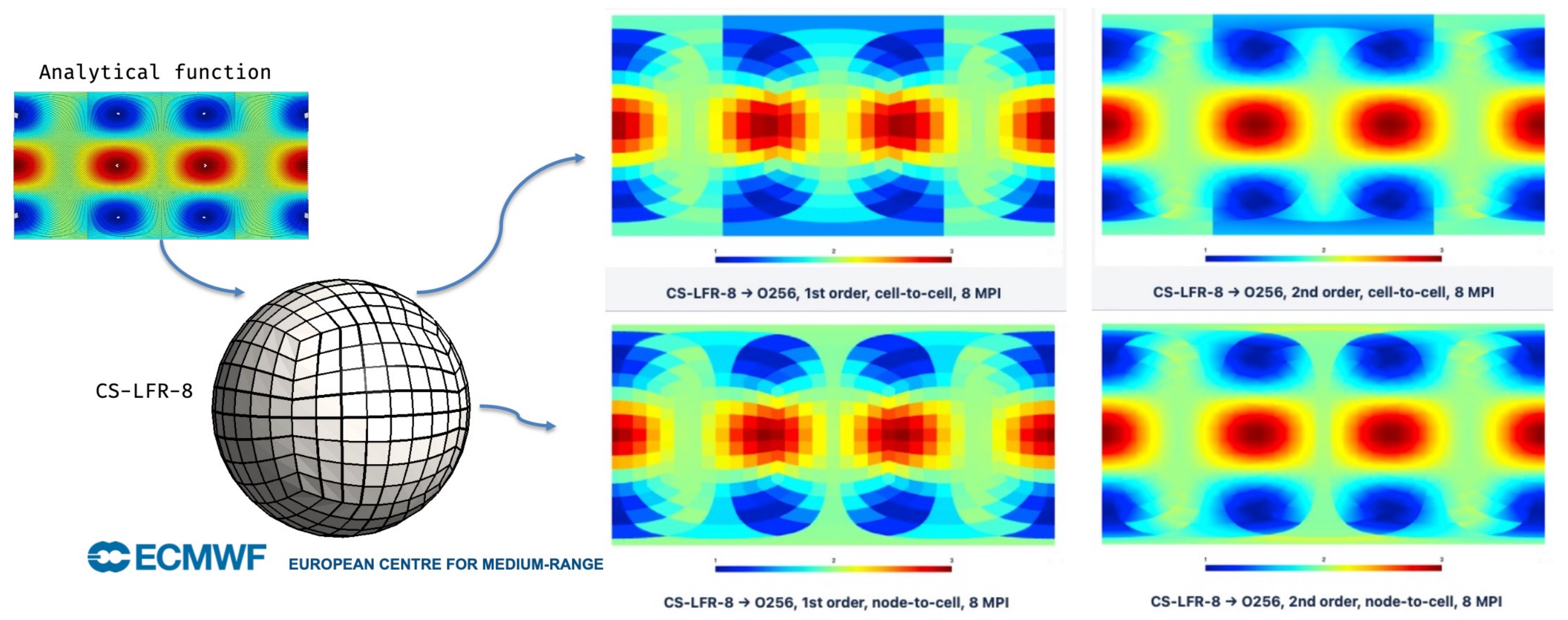

Fig 2. A staggered 1st/2nd remapping for node-to-cell and cell-to-node. Other combinations, such as node-to-node are possible as well (not shown).

3. At ECMWF

The new parallel 2nd order conservative remapping has a potential in a wide range of application at ECMWF, for instance projection IFS data to a very high resolution grids in Fig. 3.

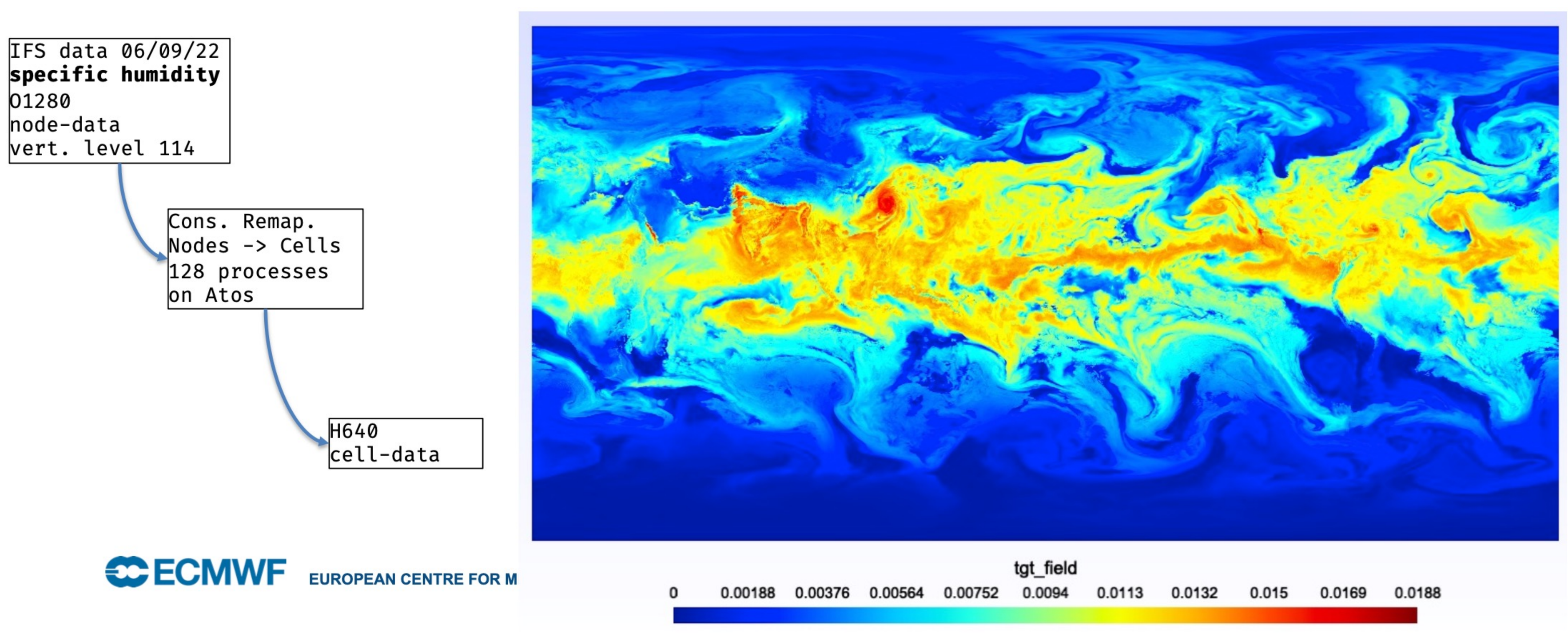

Fig. 3. (UP) Parallel higher order projection of IFS reanalysis data to a new HEALPix grid.

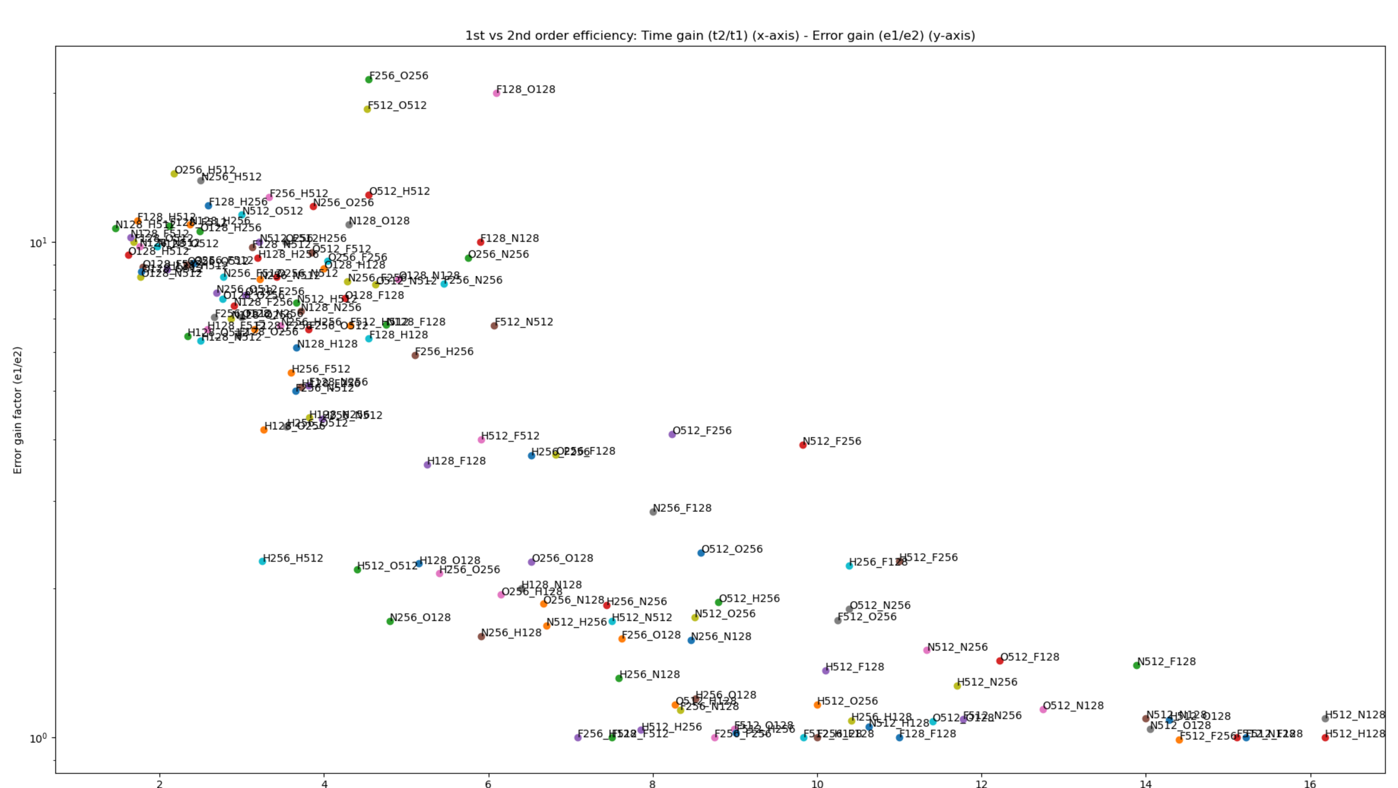

Fig 4. (RIGHT) Comparison of 1st and 2nd order remapping for IFS's typical grids. Shown is time increment of the 2nd order against the 1st order in the x-axis versus the accuracy improvement factor in the y-axis.

4. Parallelisation

Given a source and a target mesh, with a domain decomposition of a target mesh, we use Atlas' MatchingPartitioner to create a domain decomposition on the source mesh with the property that every target polygon on one MPI-partition is entirely covered by source polygons from the same MPI-partition.

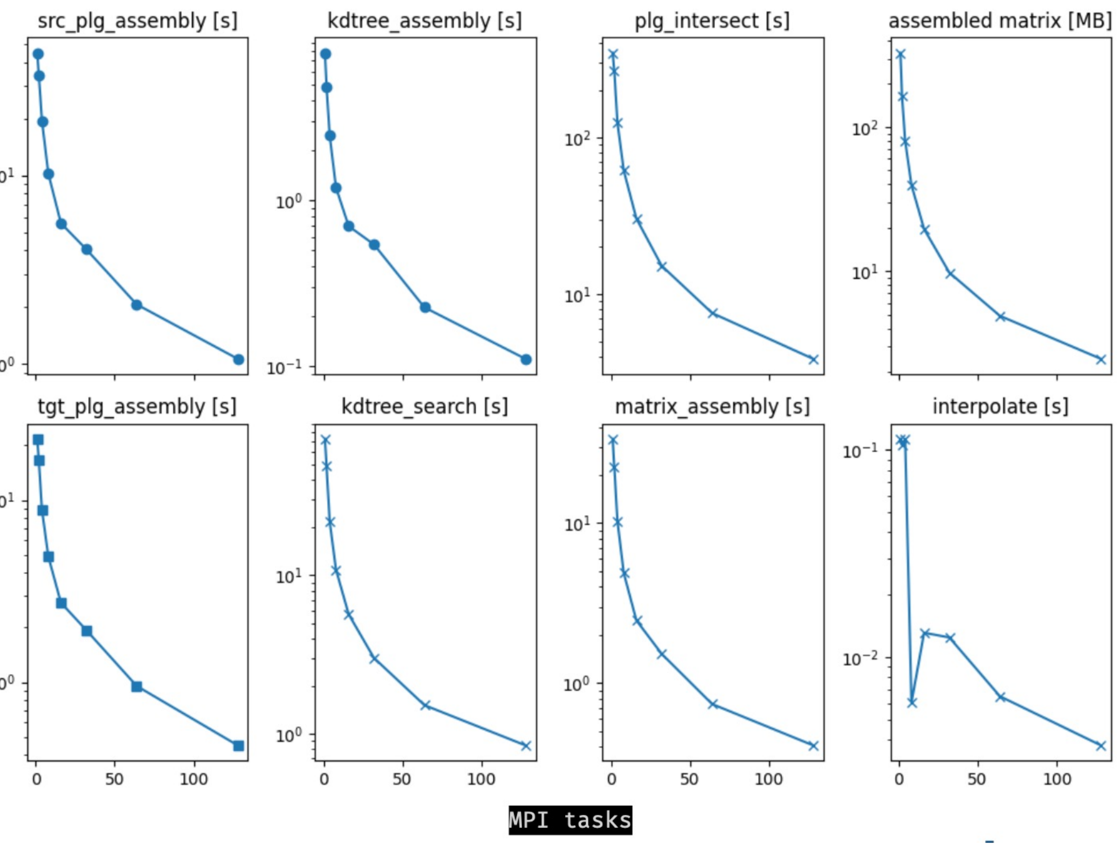

Fig. 5. A MPI-scaling of specific components of the Atlas' conservative remapping for node(O1280) → cell(H640).

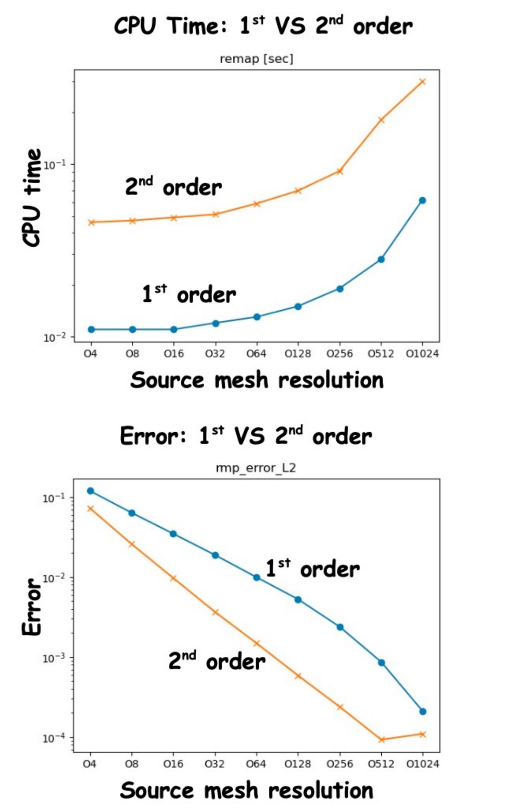

Fig. 6. Remapping O4,…, O1024 to N1024

5. A very high-resolution example

We start off with a cell-centred orographic data on regular latitude-longitude grid 43200 x 21600 to be remapped to ECMWF's operational O1280 and higher. We measured efficiency in CPU time and memory requirements in the table below.

target grid	remap order	no. nodes	tasks x threads per node	source(halo:2) → target(halo:1) tot. time, MAX(cons. remap memory / task)
O1280	o1	30	4 x 32	10.6 min, 7.5 GB
O1280	o2	30	4 x 32	14.0 min, 7.5 GB
O2560	o1	30	4 x 32	11.7 min, 9.0 GB
O2560	o2	30	4 x 32	15.6 min, 9.4 GB
O4000	o1	30	4 x 32	12.5 min, 10.9 GB
O4000	o2	30	4 x 32	17.1 min, 11.5 GB
O8000	o1	30	4 x 32	16.1 min, 16.6 GB
O8000	o2	60	2 x 32	22.3 min, 18.0 GB

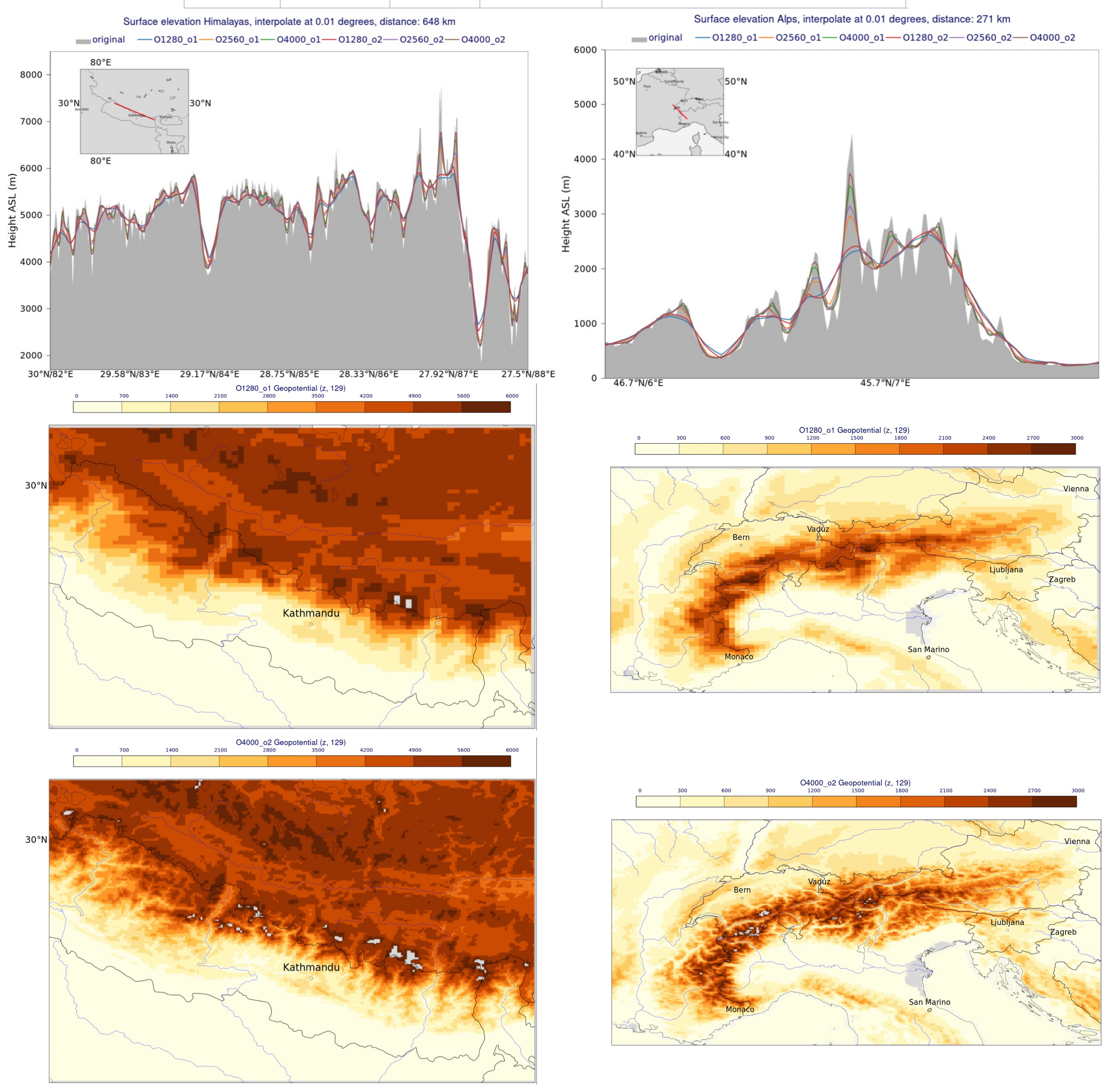

Fig 7. Remapping of regular lat-lon cell data on 43200 x 21600 to the node data on O1280 (in the second row) and O4000 (in the third row). The efficacy of the Atlas' conservative remapping is snow in cross-sectional –lots in the first row. Left column are data over Himalaya, the right column are data over Alps.

5. Acknowledgents

We are very thankful to Birgit Suezl for preparing the Python visualisation script for Fig. 7.

6. References

[1] Kritsikis et al. *Conservative interpolation between general spherical meshes,* 2017

[2] R. Loubere, M. J. Shashkov, *A subcell remapping method on staggered polygonal grids for arbitrary-Lagrangian-Eulerian methods,* 2005

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