OASIS Gaussian interpolation
with locally relative source-target distances

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Abstract

We change the definition of the weights calculation in the OASIS Nearest-Neighbours Gaussian interpolation. In this calculation, instead of a global average of the distance between all source grid points, we use a local average of distance between the source neighbours only. The algorithm preserves the MPI-OpenMP parallellisation and its computing performance. It is shown in several examples that the interpolation error, measured on analytic fields, is slightly reduced compared to the simple distance weighted interpolation, assuming that the user provides the appropriate value of the parameter that modifies the distance variance in the weight formula. However, we estimate that the enhancement remains small compared to the effective resolution of the model

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1. Rationale

The OASIS [1] coupling library includes an automatic definition of spatial and horizontal interpolations on the sphere that enables the exchange of model coupling fields discretised on different grids. Several kinds of interpolation are provided via the SCRIP library [2], made available in a hybrid MPI-OpenMP parallel version [3]. One of them, named GAUSWGT (hereafter *G interpolation*) is a variant of the standard nearest neighbours algorithm, named DISTWGT (hereafter NN interpolation). Both builds the interpolated result with quantities located on the N nearest source grid points of the target grid point (N is a user defined parameter). Both relies on the "D" distance between the target grid point and any source grid point neighbours to calculate the weight of this neighbour contribution to the interpolated quantity. But weights of the NN interpolation are proportional to :

$$1/D$$

and weights of the G interpolation are proportional to :

$$EXP(-1/2 \, . \, D^2/\sigma^2)$$

where σ^2 is the square of the average distance between source grid points "d", multiplied by a factor *VAR* defined by the user via the OASIS parameter file (namcouple) :

$$\sigma^2 = VAR \, . \, d^2$$

The G interpolation formula links the weight with a relative distance D/d, instead of an absolute distance D in the NN interpolation formula.

In the original Californian algorithm, probably written for 1D cases, this average distance was performed in a loop following the indexes of the whole source grid point array. Distances were calculated between points of two consecutive addresses of the array, added and divided by the number of source grid points. The average distance "d" was the average of the distance between all consecutive grid point centers of the source grid.

This algorithm has two drawbacks:

- with varying resolution discretisations (actually the case of most of the geophysical grids, except icosahedral), the global averaged distance can be very different from the distances between the source grid point used locally to perform the interpolations
- at the opposite of 1D grid cases, two consecutive grid points in the 2D array could easily not be neighbours (e.g. at boundaries of a regional grid)

To address these two issues, a local and parallel algorithm, already proposed in [4], is implemented. For each target point, the average distance "d" is calculated only between non masked neighbours of the source grid. The coefficient applied to calculate relative distances is now local to the target grid point. The locality of the formula guarantees its validity whatever the order the grid points are declared in the array. It also ensures that the relative source-target distance is now relative to a local inter-source grid point distance, which is more

meaningful than a global distance, specially in case of resolution varying discretisations.

2. Implementation

The original and sequential routine necessary to calculate the global average of consecutive source grid point centers is deleted. It is replaced, in the MPI-OpenMP parallel loop on target grid points, by a local calculation of the distance between non masked source neighbours. If two source neighbours are identified, the local σ coefficient is calculated and applied to the inverse of the target-source distance. If not, it is this inverse of the target-source distance that will be used to calculate the weights. In this later case, the weights are those of a simple NN interpolation.

3. Validation

Since the σ coefficient is now calculated in parallel, one must be sure that the weight and address variables defining the interpolation are identical for several hybrid decompositions (*reproducibility validation*). This is done comparing source address, target address and weight variables of the OASIS remapping files obtained with 1,2,4,8,20 and 40 OpenMP threads and 40 OpenMP threads + 2,4,8,16,32,64,128 and 256 nodes. Calculation are performed on the `beaufix` Intel Broadwell supercomputer at Météo-France.

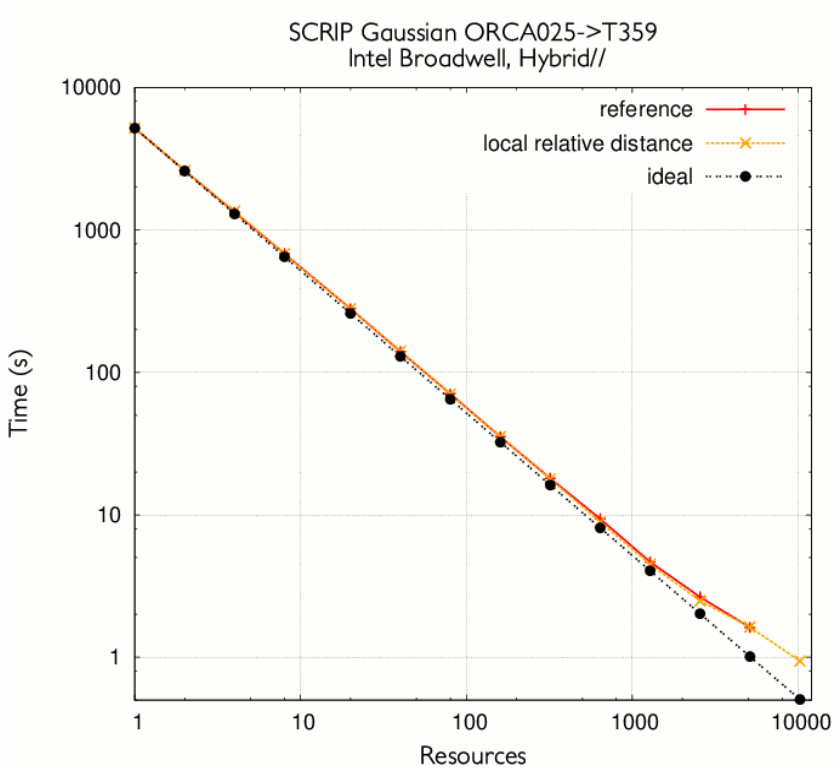

Figure 1: Scalability of W&A calculations for Gaussian SCRIP interpolations at high resolution (logarithmic axes) before and after modification of σ coefficient

In a second step, we check that our modification does not downgrade the restitution time of the weight calculation, for any decomposition (*computing performance validation*). Raw restitution time before/after implementation are plotted in Figures 1. Differences has no statistical significance, regarding to the machine restitution time reproducibility.

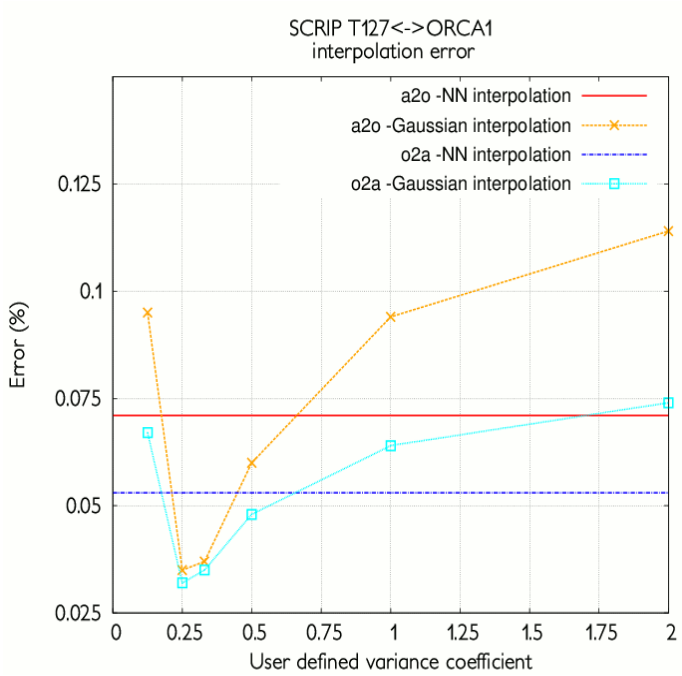

Figure 2: G- and NN- interpolation error of an analytic field, from T127/ORCA1 (a2o) and back (o2a), as a function of the VAR user defined coefficient

In a third step, we evaluate the impact of our modification on the quality of the interpolation. To do so, we compare an interpolated analytic field with the same analytic field calculated on the target grid, following the procedure described in [5] (*algorithmic validation*).

It is immediately clear that the user defined VAR coefficient has an impact on interpolation quality. Figure 2 shows the globally averaged value of the error (%). The source and target grids are those of the ARPEGE & NEMO models (CNRM-CM6-LR): the T127 atmosphere Gaussian reduced grid and the ORCA tripolar at 1 degree resolution respectively. With G interpolation, using 4 neighbours, different values of VAR are tested (orange and light blue lines). A minimum is found on both cases. For comparison, the NN interpolation error is also plotted (red and dark blue lines). The minimum G error (also using 4 neighbours) is smaller than the NN error, which confirms that, with an appropriate VAR value, the Gaussian option can enhance the results of the NN interpolation. However, erroneous values of VAR could downgrade the interpolation quality so that the G interpolation gives worse results than the NN interpolation. Nevertheless, errors have small raw values, which indicates that the gain, that can be seen as a smaller error on the position of the interpolated field, is most of the time negligible compared to the effective resolution of the model.

The visualisation of the error spatial pattern (shown in upper Figures 3) confirms that the enhancement brought by the Gaussian option (right), in comparison to the NN (left) looks like a noise reduction. We deduce from the positive value of the difference (Figure 3, lower left) that the error is reduced everywhere, except in Arctic regions where NN error is already high.

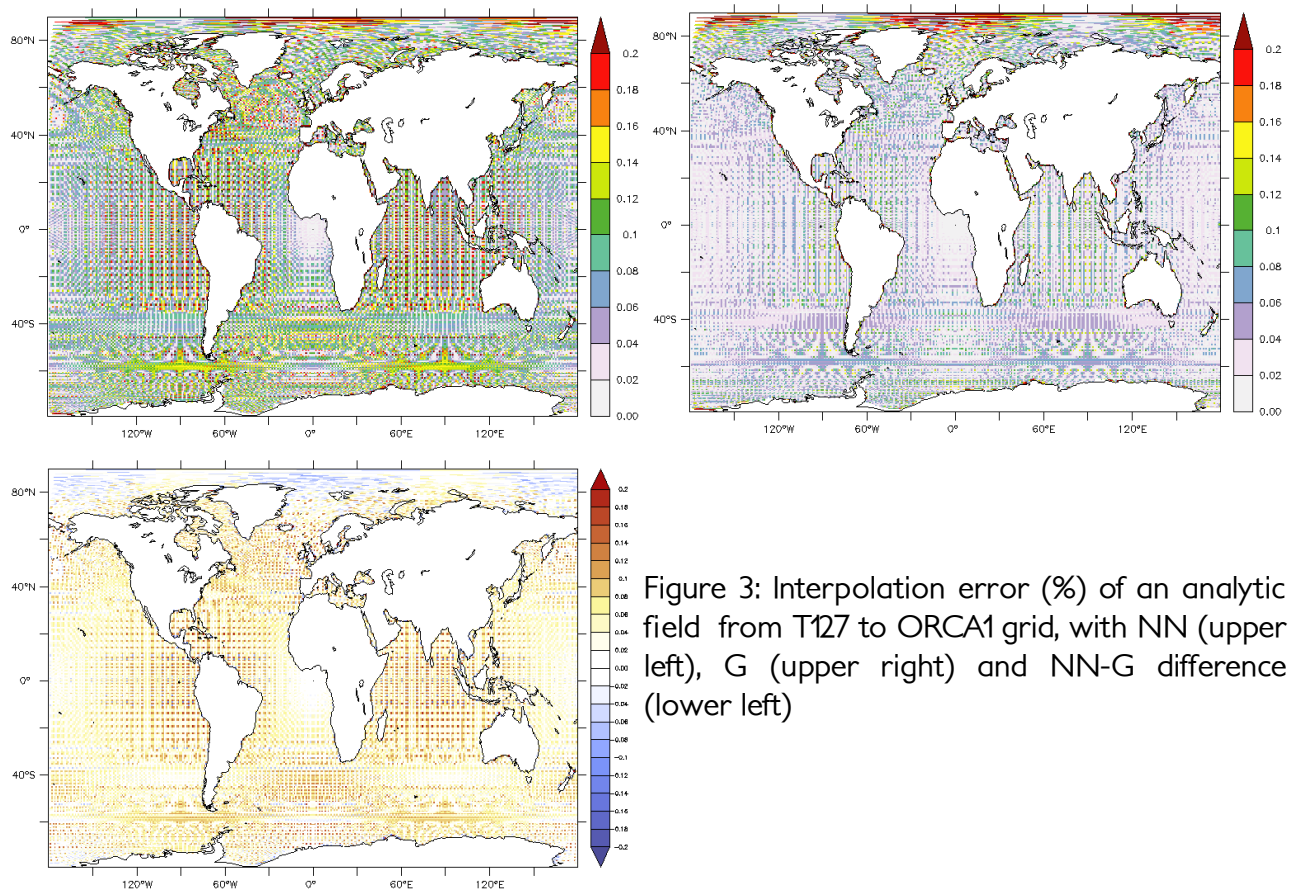

Figure 3: Interpolation error (%) of an analytic field from T127 to ORCA1 grid, with NN (upper left), G (upper right) and NN-G difference (lower left)

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References

[1] Craig A., Valcke S., Coquart L., 2017: Development and performance of a new version of the OASIS coupler, OASIS3-MCT_3.0, Geosci. Model Dev., 10, pp. 3297-3308, doi:10.5194/gmd-10-3297-2017

[2] Jones, P., 1999: Conservative remapping: First-and second-order conservative remapping, Mon. Weather Rev., 127, 2204–2210

[3] Piacentini, A., Maisonnave, E., Jonville, G., Coquart, L. and Valcke, S., 2018: A parallel SCRIP interpolation library for OASIS , Working Note, **WN/CMGC/18/34**, CECI, UMR CERFACS/CNRS No5318, France

[4] Hanke, M., Redler, R., Holfeld, T., and Yastremsky, M., 2016: YAC 1.2.0: new aspects for coupling software in Earth system modelling, Geosci. Model Dev., 9, 2755-2769, https://doi.org/10.5194/gmd-9-2755-2016

[5] Jonville, G., Valcke, S., Coquart, L., Maisonnave, E. and Piacentini, A., 2018: Specific analyses of the SCRIP interpolation library for OASIS coupler , Working Note, **WN/CMGC/18/93**, CECI, UMR CERFACS/CNRS No5318, France