Analysis of SCRIP conservative remapping in OASIS3-MCT – Part B

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1. Introduction

This report analyses the impact of the different normalisation options and the Lambert projection for the SCRIP 1st order conservative remapping (CONSERV) for different grids. Contrary to TR-CMGC-19-129, this report considers the maximum of the interpolation error over the whole domain and not just for the polar cell. In particular, for the Gaussian Reduced grid, the impact of redefining the corners of the cells so that a cell on one latitude row include also the original corners of the upper and lower latitude rows is evaluated.

The general conclusion is that CONSERV with the FRACAREA normalisation gives good results for all grid couples and, in some cases, only if the Lambert projection is not activated. For DESTAREA, remappings involving the Gaussian Reduced grid always show some problems, even if the corners are redefined as explained above. For DESTAREA remappings involving grids other than the Gaussian Reduced grid show reasonable results; for some couples, Lambert projection is mandatory, for other Lambert projection should not be activated, and for other the Lambert projection does not change the results.

The grids tested are the same than in TR-CMGC-19-129, i.e.:

- NOGT : NEMO ORCA1 logically rectangular grid, 362x294 points
  - columns with i=1,2 overlap columns with i=361,362 and columns with i=1 and i=362 are masked ;
  - row with j=294 is masked as it overlaps row with j=293 ;
  - cell 105970 is a "polar" cell in the SCRIP sense since a cell border between the corners located at (253.0, 89.6213) to (73.0 , 89.9417) crosses the North pole.
- BGGD : LMDz regular latitude-longitude grid, 143x144 points
  - its last latitude row is formed of 143 degenerated triangular cells going to the pole (the two original upper corners overlap); there is no polar cell in the SCRIP sense.
- ICOS : DYNAMICO icosahedral grid, 15212 points
  - cell 15211 covering the North pole is a "polar" cell in the SCRIP sense as it covers the pole.

For the Gaussian Reduced ARPEGE T127 grid (24572 points), two definitions are considered, SSEA4v and SSEA7v, as explained in the next section.

2. Two definitions for Gaussian Reduced ARPEGE T127 grid, SSEA4v and SSEA7v

The Gaussian Reduced grid consists of 24572 cells, each one originally defined by 4 vertices (corners). “Reduced” means that from a certain latitude row the number of cells on the row is decreasing while the North Pole is approaching. It involves that the vertices of the cells on specific latitude row do not coincide with the vertices of the cells of the upper or lower latitude rows. The surface of the globe is not completely cover, some small holes are present. In this report, the grid defined as such is referred to with the SSEA4v acronym.

To improve conservative remapping for the Gaussian Reduced grid the need to redefine the grid, so that a cell on one latitude row include also the original corners of the upper and lower latitude rows, has emerged.

A Python tool has been developed, named "build_ssea7crn.py", to rebuild the grid cells with more than 4 vertices for each cell in a way that all the surface of the globe will be covered, without holes.

In a first time two lists are built:
- a global list of the cell vertices of the grid
- a list of the cell connectivity describing how the vertices are connected together to form each cell

In a second time each cell is redefined with a maximum of 7 vertices. Then all cells are defined with 7 vertices. For the "regular" cells (of the cartesian part of the grid) with 4 vertices or for the cells with 5 or 6 vertices, the last vertex is repeated to complete the definition of the cell to 7 vertices. In this report, the grid defined as such is referred to with the SSEA7v acronym.

Figure 1 below shows polar views of the Gaussian Reduced grid with both descriptions of the cells, the original one with a 4-vertex cell description in blue, and the new one with a 7-vertex cell description in red.

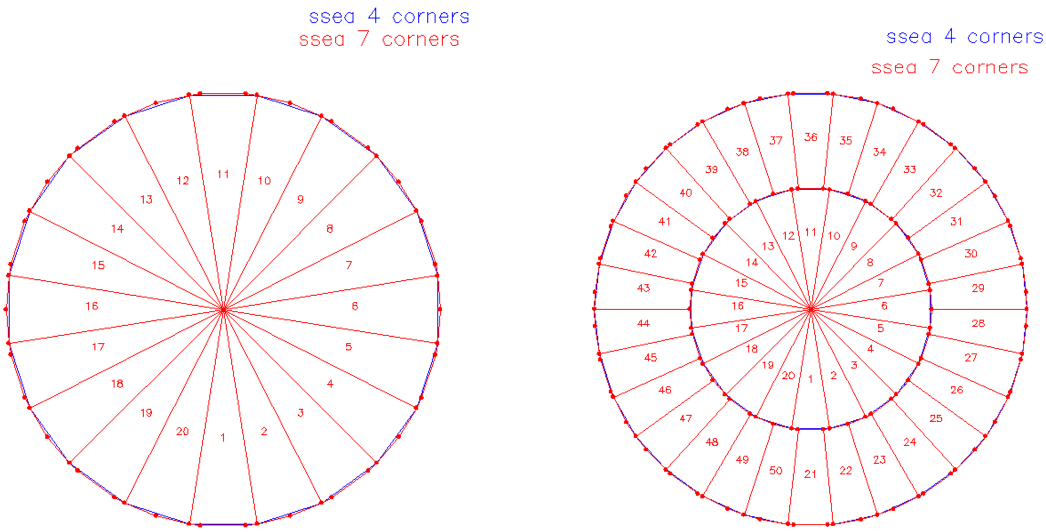


Figure 1: Definition of the Gaussian Reduced grid with 4 vertices (SSEA4v in blue) or with 7 vertices (SSEA7v in red)

3. Analysis of remapping maximum error for different couples of grids

The maximum of the remapping error is analysed here for different remappings with different options for different grids. The remappings are the ones available in OASIS3-MCT[1] :

- DISWGT with 1 or 4 nearest neighbours, DISTWGT(1) or DISTWGT(4)
- BILINEAR
- BICUBIC
- CONSERV 1st order with DESTAREA normalisation option
- CONSERV 1st order with FRACAREA normalisation option (FRACAREA 1st)
- CONSERV 2nd order with FRACAREA normalisation option (FRACAREA 2nd)

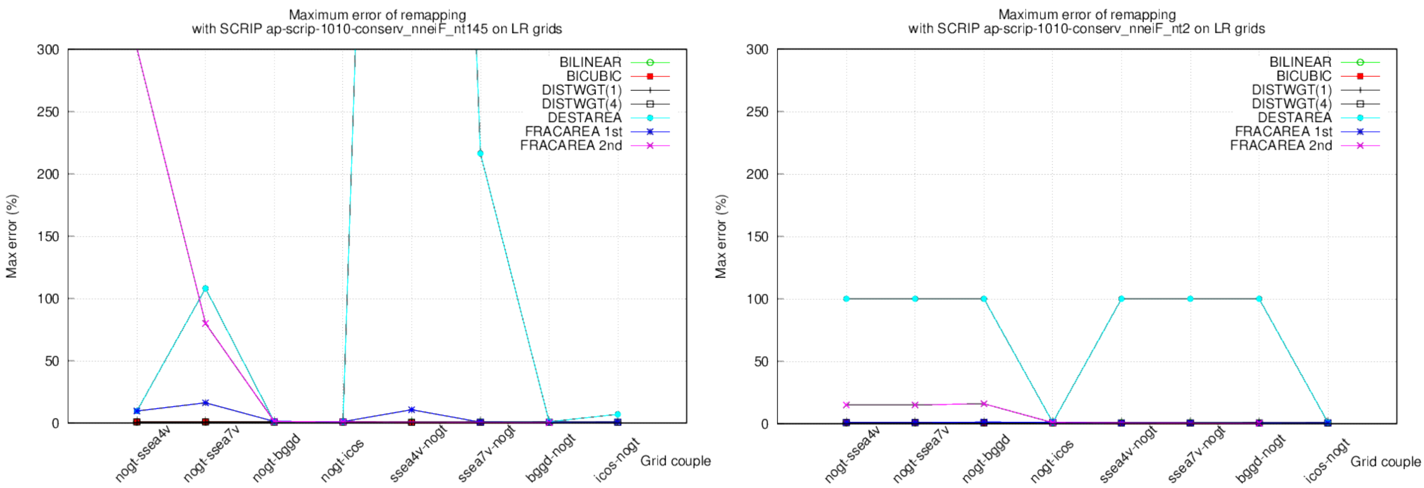
[1] For details, see section 4.3 of OASIS3-MCT User Guide, https://cerfacs.fr/wp-content/uploads/2018/07/GLOBC-TR-oasis3mct_UserGuide4.0_30062018.pdf

These algorithms originally come from the SCRIP library (Jones 1999[2]) but for the bilinear and bicubic algorithm when the source grid is a Gaussian Reduced grid, i.e. SSEA4v and SSEA7v, which uses an in-house-developed algorithm.

To quantify the remapping error, the `test_interpolation` environment available with the OASIS3-MCT sources, is used. `Test_interpolation` couples two component models, model1 and model2, and calculates the remapping error on the target grid. Only one coupling exchange is performed at t=0. The values of the coupling field are defined by an analytical function on model1 grid. The remapping error is defined as the difference between the values of the coupling field remapped on the target grid and the values of the analytical function on the target grid points, divided by the remapped field (and multiplied by 100 to have it in %).

Here we present the maximum of the remapping error for the different remappings for the different couples of grid, activating or not the Lambert projection above 83.08 deg N (1.45 radians)[3,4]. For more details about the Lambert projection, please refer to section 4 of TR-CMGC-19-129.

For DESTAREA, a big error along the coasts is intrinsically linked to this normalisation as the total target cell area is used to normalise each target field value even if its corresponding cell only partly intersects non-masked source grid cells; local flux conservation is ensured, but unreasonable field values may result. Here we are not interested in this error along the coast and we excluded the coast cells in our calculation of the maximum error. The coast cells are identified using the fractional mask of the target grid (the cells with a fractional mask < 0.99 are rejected), or, when the target grid is the NOGT grid that does not have a fractional mask, using the 2D-plot of the maximum error and visually omitting the points along the coast.



(a) with Lambert projection

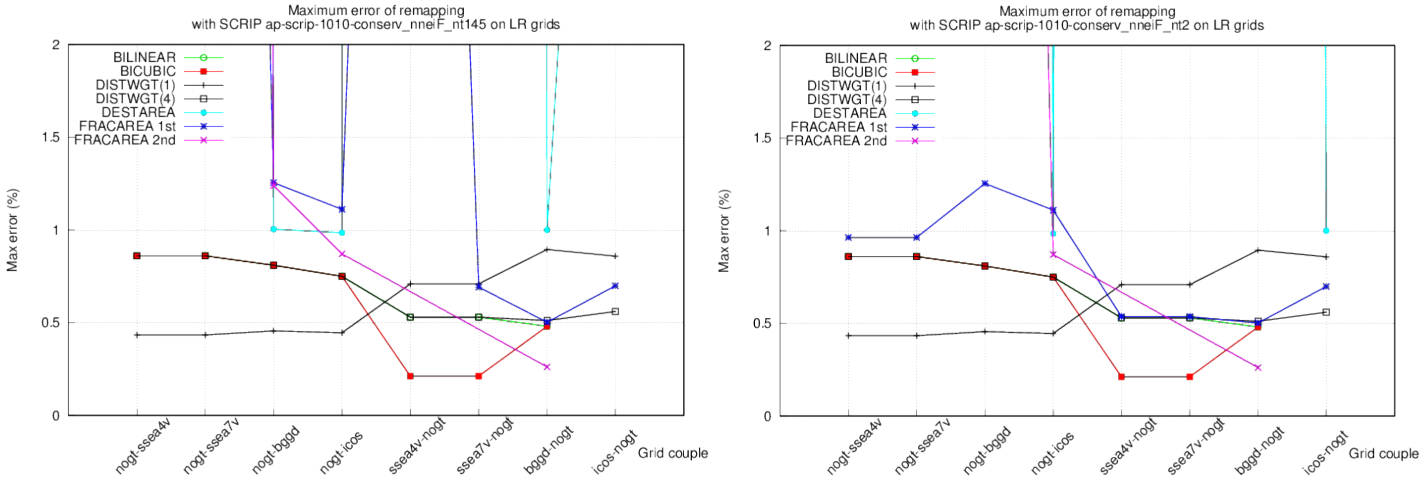
(b) with no Lambert projection

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

[3] These results are also presented in https://inle.cerfacs.fr/attachments/8065/LambertOrNot.pdf .

[4] Geographic details of the remapping error, when the Lambert projection is activated, can be found in the document at https://inle.cerfacs.fr/attachments/download/8063/interpolErrors_PSCRIP_LR_ap-scrip-1010-conserv_nneiF_ssea7v.pdf . The cases examined in that document are the same than the ones examined here with Lambert projection, except that the SSEA4v grid is not included and that the error along the coast is not excluded for DESTAREA.

Figure 2- Maximum remapping error up to 300%



(a) with Lambert projection

(b) with no Lambert projection

Figure 3- Maximum remapping error up to 2% (zoom)

We see that the maximum errors are very reasonable (below 1%) for the DISTWGT(1) or DISTWGT(4), BILINEAR and BICUBIC remappings.

For the 1st order conservative remappings (we won't comment the 2nd order results), the analysis of the impact of the Lambert projection and of the new definition of the Gaussian Reduced grid is somewhat more delicate. We can conclude:

- For FRACAREA 1st :
  - with no Lambert projection (dark blue Fig 2b and 3b), the error is reasonable for all couple of grids
  - activation of Lambert projection significantly degrades the results for NOGT->SSEA4v (9.6% max error) and NOGT->SSEA7v (16.1% max error) (to be compared with ~0.9% without Lambert); contrary to what was expected, the 7-vertex definition of the Gaussian Reduced grid worsen the results;
  - activation of Lambert projection significantly degrades the results for SSEA4v->NOGT (10.7% max error); in this -and only- case, the 7-vertex definition seem to solve the problem (0.7% max error for SSEA7v->NOGT); but the error without Lambert is in both cases smaller (~0.6%)
  - for the other couples of grids, activation of Lambert projection does not significantly change the results.
- For DESTAREA:
  - Activation of Lambert projection is mandatory for both NOGT->BGGD BGGD->NOGT: the max error drops down from 100% without Lambert to 1% with Lambert which is reasonable
  - For SSEA4v/7v->NOGT, results are bad with and without Lambert projection; activation of Lambert projection even degrades the results: max error goes from 100% to 1000% for SSEA4v->NOGT and from 100% to 220% for SSEA4v/7v->NOGT

- For NOGT->SSEA4v/7v, results are bad with and without Lambert projection; activation of Lambert improves the results for NOGT->SSEA4v (max error goes from 100% to 10%) but degrades them for NOGT->SSEA7v (max error goes from 100% to 110%)
- For NOGT->ICOS, results are OK with and without Lambert with a max error of 1%
- For ICOS->NOGT, Lambert projection degrades significantly the results which are fine without Lambert (error max of 1%) but get wrong with Lambert (error max of ~7%)

The tables below summarize the results.

Green is used when the maximum error stays below 1.5%, and red when it is above i.e. when the remapping shows significant error. *Lambert* is indicated when the Lambert projection reduces the maximum error, *no Lambert* when the maximum error is smaller without Lambert projection. The sign = is used when the results are not significantly different with or without Lambert projection.

NOGT as a source grid

	nogt-ssea4v	nogt-ssea7v	nogt-bggd	nogt-icos
FRACAREA 1st	*no Lambert*	*no Lambert*	=	=
DESTAREA	*Lambert*	*no Lambert*	*Lambert*	=

NOGT as a target grid

	ssea4v-nogt	ssea7v-nogt	bggd-nogt	icos-nogt
FRACAREA 1st	*no Lambert*	*no Lambert*	=	=
DESTAREA	*no Lambert*	*no Lambert*	*Lambert*	*no Lambert*

In summary:

- For FRACAREA 1st, the remapping gives good results for all grid couples and in some cases, only if the Lambert projection is not activated.
- For DESTAREA, remappings involving the SSEA4v or SSEA7v grid always show problems; the Lambert projection even gives worst results except for the NOGT->SSEA4v case.
- For DESTAREA, remapping not involving the SSEA4v or SSEA7v grid show reasonable results; for some couples, Lambert projection is mandatory (NOGT<->BGGD), for other Lambert projection should not be activated (ICOS->NOGT), and for other the Lambert projection does not change the results (NOGT->ICOS).