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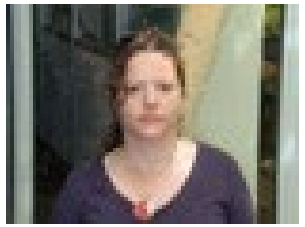
OASIS3-MCT_5.0
the latest version of the OASIS coupler

is-enes
INFRASTRUCTURE FOR THE EUROPEAN NETWORK FOR EARTH SYSTEM MODELLING

esiwace
CENTRE OF EXCELLENCE IN SIMULATION OF WEATHER AND CLIMATE IN EUROPE

Oasis

S. Valcke L. Coquart G. Jonville E. Maisonnave A. Piacentini A. Craig



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OASIS3-MCT_5.0
the latest version of the OASIS coupler

Some generalities : history, community, API, communication, …

New in OASIS3-MCT_5.0

Benchmarking of regridding libraries

Conclusions and perspectives

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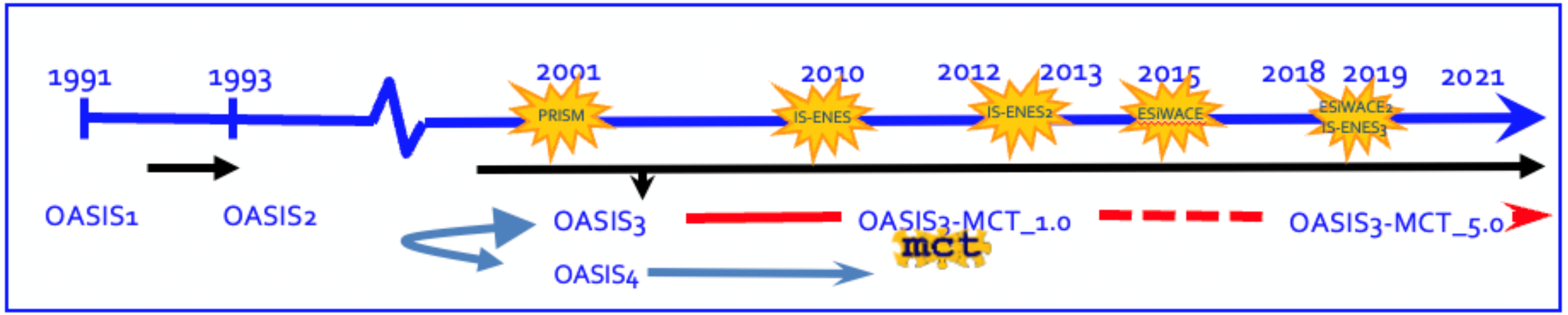
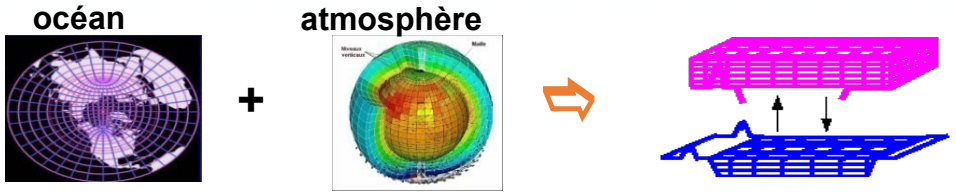
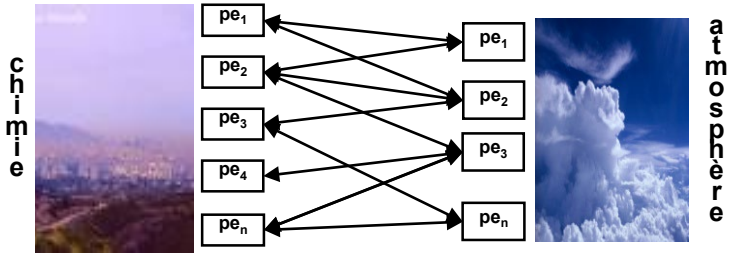
OASIS, a long long story …



- OASIS1 -> OASIS2 -> OASIS3:
  2D ocean-atmosphere coupling
  low frequency, low resolution :
  → Flexibility, 2D interpolations

- OASIS4 / OASIS3-MCT:
  2D/3D coupling of high-resolution parallel components
  →Parallelism, performance





OASIS: many, many users …

2019 survey

67 climate modelling groups around the world use OASIS3-MCT …

…. to assemble more than 80 coupled applications !!

OASIS3-MCT is used in 5 of the 7 European ESMs that participated to CMIP6

OASIS3-MCT: some generalities

- All sources are written in F90 and C
- Uses the Model Coupling Toolkit (MCT) from Argonne National Lab
- Open source product distributed under a LGPL license
- All external libraries used are public domain (MPI, NetCDF) or open source (LANL SCRIP, MCT)
- Current developers are:
  - ~1 permanent FTE (CERFACS, CNRS): Eric Maisonnave, Laure Coquart, Sophie Valcke
  - 2 consultants : Anthony Craig (also CPL7 and ESMF), Andrea Piacentini

ESiWACE H2020 EU Centre of Excellence
- ESiWACE1 (2015-2019): 18 pm
- ESiWACE2 (2019-2023): 16 pms

IS-ENES EU FP7 project
- IS-ENES2 (2014-2017): 27 pm
- IS-ENES3 (2019-2023): 35 pms

IS-ENES3 and ESiWACE2 have received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824084 & No 823988

TRACCS French national project (2024-2030, 6 PYs)

OASIS3-MCT code interfacing

- Initialization: `call oasis_init_comp(...)`
- Local partition definition: `call oasis_def_partition (...)`
- Grid definition: `call oasis_write_grid (...)`
- Coupling field declaration: `call oasis_def_var (...)`
- End of definition phase: `call oasis_enddef (…)`
- Coupling field exchange:
  - in model time stepping loop

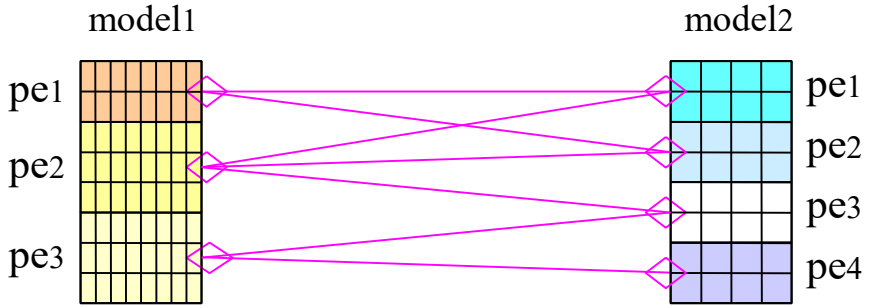
```
call oasis_put (…, date, var_array. …)
call oasis_get (…, date, var_array, …)
```

- user defines externally the source or target
- sending or receiving at appropriate time only
- automatic averaging/accumulation if requested
- automatic writing of coupling restart file at end of run

- Termination: `call oasis_terminate (…)`

OASIS3-MCT parallel communication

• Fully parallel communication between parallel models based on Message Passing Interface (MPI)



Coupling exchanges between **two separate concurrent executables** but also between **two concurrent** or **sequential components** within **one same executable (OASIS3-MCT_3.0)**

Configuration of each coupling exchange in a **text** file *namcouple*

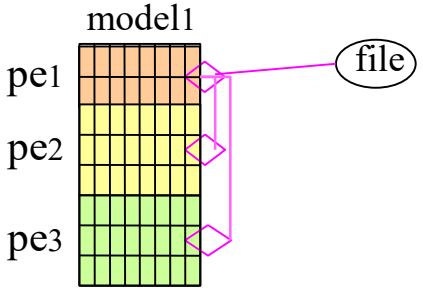
- source and target symbolic name (end-point communication)
- exchange period
- transformations/interpolations

Interpolation/regriddding weights and addresses can be calculated

- offline with SCRIP, ESMF or XIOS in the unified environment
- online with SCRIP

new in OASIS3-MCT_5.0

• I/O functionality (switch between coupled and forced mode):

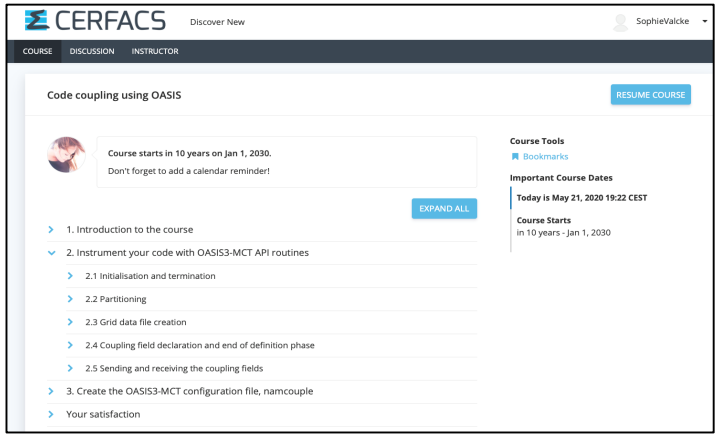


New in OASIS3-MCT_5.0 (12/2021)

Source management and training

- Migration from SVN to GIT, full history
- New web site: https://oasis.cerfacs.fr/
- New Short Private Online Course (SPOC)
  - 20 hours on-line over 2 weeks: theory, videos, quizzes, hands-on with verification
  - instrument two toy models to set-up a coupled model exchanging one field in each direction
  - section on regridding/interpolation

✓ already 3 sessions, 22 participants, good overall feedback

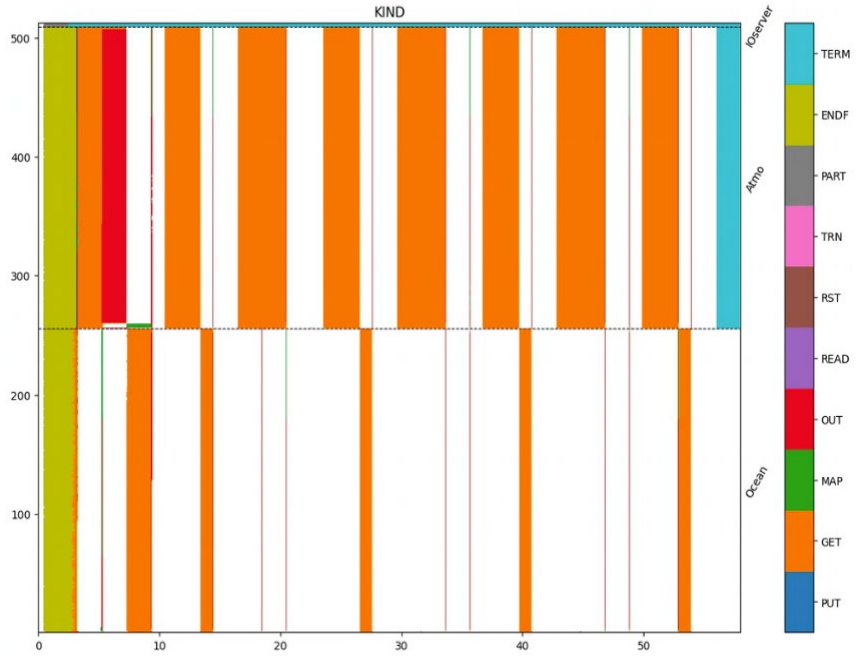


New in OASIS3-MCT_5.0 (12/2021)

Tools / interface

- New Python, C & C++ bindings
  - SMHI : standalone regridding weight computation tool
  - INRIA: coupling between CROCO ocean model and trained IA model for downscaling atmospheric fluxes

- New load balancing tool (ex lucia) with graphical output of the coupling exchanges



New in OASIS3-MCT_5.0 (12/2021)

Regridding / interpolation / ensembles

- Extension of oasis_get_intracomm for coupled models involving XIOS for ensemble simulations
- Locally-conservative runoff interpolation : no surface intersection, every source point needs a target neighbour
- Unified environment to use SCRIP, ESMF or XIOS offline to pre-calculate regridding weights
- Extensive benchmark of the regridding for SCRIP, ESMF, XIOS & YAC

Valcke et al 2022, https://doi.org/ 10.3390/mca27020031
Valcke et al 2021, Cerfacs Tech Report, TR-CMGC-21-145

Benchmarking of regridding libraries

Context

Good-quality and performant regridding/remapping/interpolation in couplers identified as one important challenge in climate modelling

5th Workshop on Coupling Technologies for ESMs (S. Valcke, BAMS, doi:10.1175/BAMS-D-21-0045.1)

Detailed analysis of SCRIP library in OASIS3-MCT concluded on the need to offer other regridding possibilities in the coupler

Jonville & Valcke 2019, Cerfacs Tech Report, TR-CMGC-19-155

Valcke & Piacentini 2019, Cerfacs Tech Report, TR-CMGC-19-129

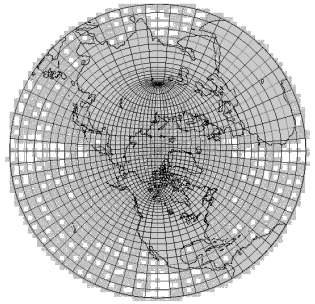
After an initial analysis, we decided to evaluate quality and performance of :

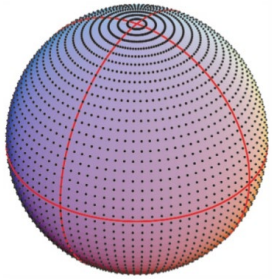
- YAC (DKRZ; DE)
- ESMF (NASA, NOAA, DoD, NSF; USA)
- XIOS (IPSL/CEA, FR)

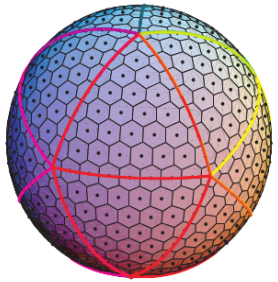
Benchmarking of regridding libraries – grids

14 pairs of grids involving 6 grids:

- torc: NEMO ORCA2 rotated-stretched logically-rectangular (182x149)
- nogt : NEMO ORCA1 rotated-stretched logically-rectangular (362x294)
- bggd: LMDz regular lat-lon (144x143)
- sse7: ARPEGE Gaussian reduced T127 (24572)
- icos: Dynamico icosahedral grid (15222)
- icoh: Dynamico icosahedral grid (2016012)

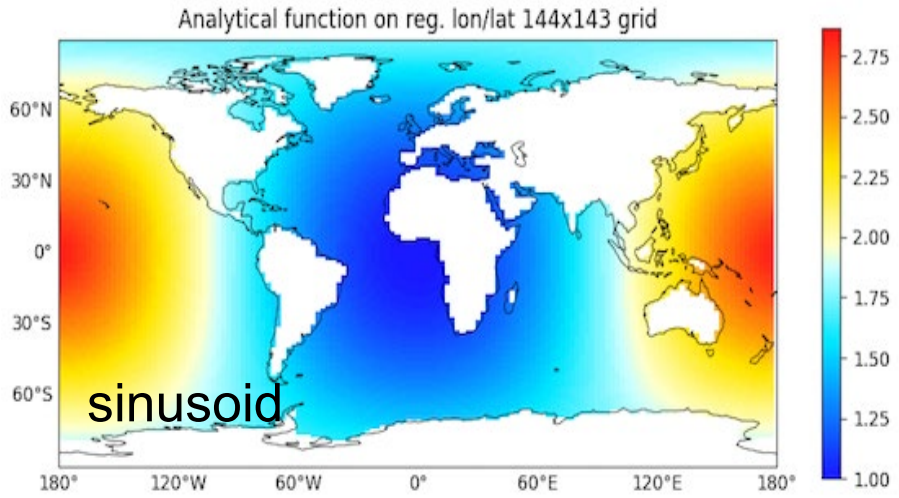


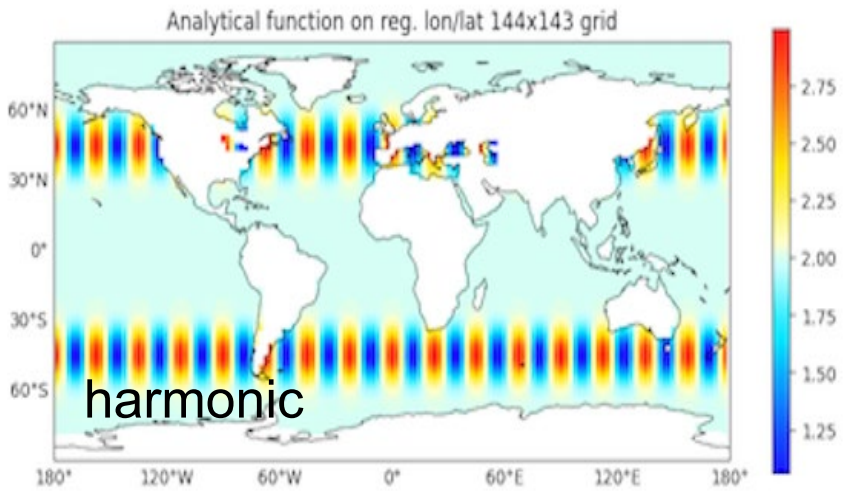


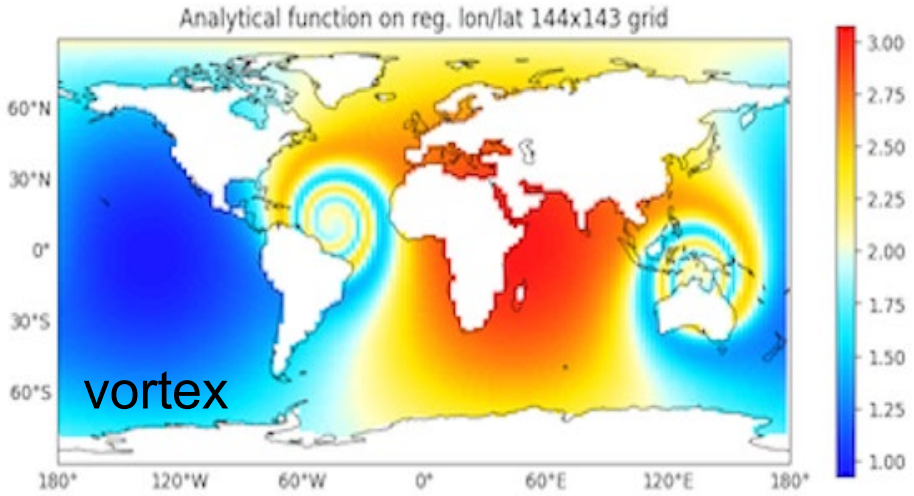


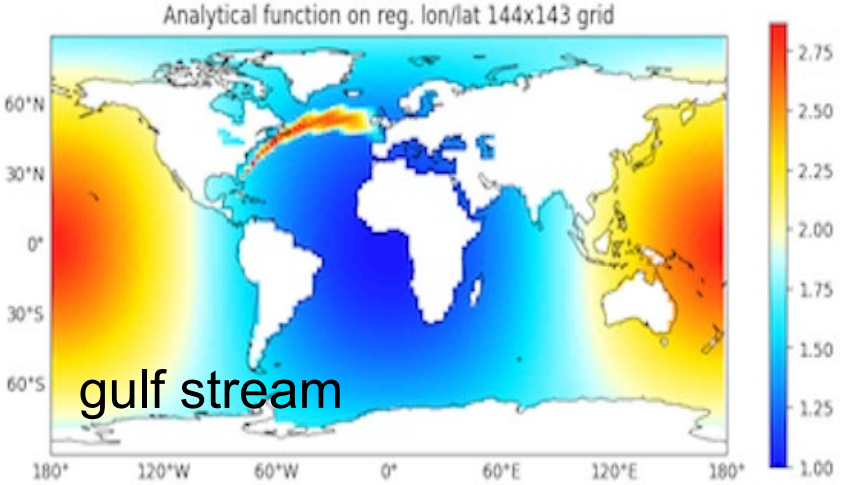
Benchmarking of regridding libraries – test cases

4 functions:









5 algorithms: nearest-neighbour, bilinear, bicubic, 1st and 2nd order conservative

Benchmarking of regridding libraries - metrics

From CANGA project (https://github.com/CANGA/Remapping-Intercomparison)

Ψ^s *Analytical function on source grid* Ψ^t *Analytical function on target grid* $\mathbf{R}\Psi^s$ *Source analytical function regridded on target grid*

- sensitivity : algorithmic invariance to underlying mesh topology
  - ✓ test cases with 14 pairs of grids
- consistency: accuracy and preservation of discretization order
  - ✓ accuracy: misfit mean, max, rms

$$\text{mean}\frac{|\mathbf{R}\Psi^s - \Psi^t|}{|\Psi^t|} \qquad \max\frac{|\mathbf{R}\Psi^s - \Psi^t|}{|\Psi^t|} \qquad \sigma\frac{|\mathbf{R}\Psi^s - \Psi^t|}{|\Psi^t|}$$

- conservation:
  - ✓ conservation

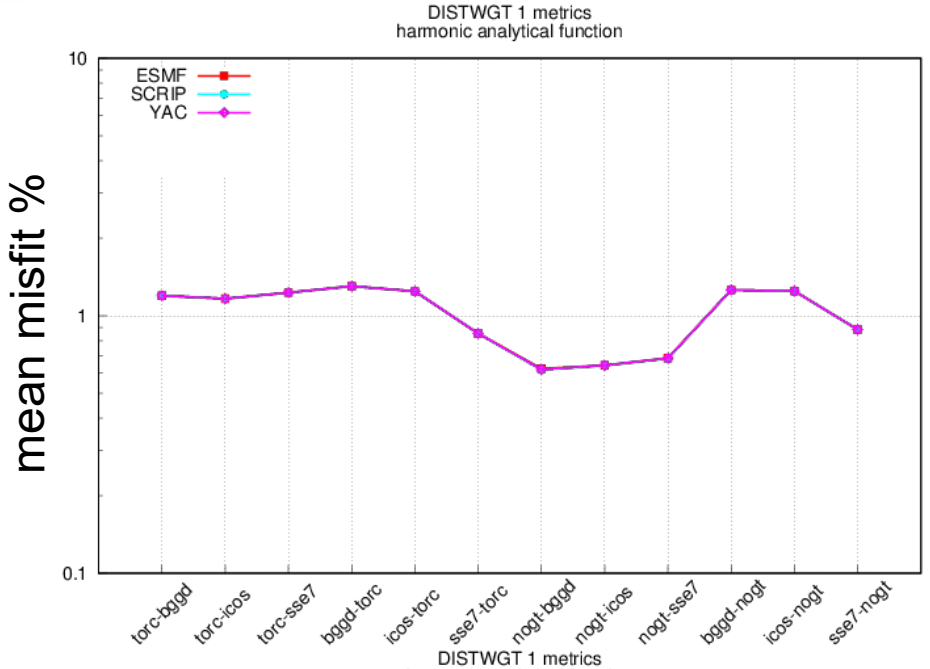
$$\frac{|I_t(\mathbf{R}\Psi^s) - I_s(\Psi^s)|}{I_s(\Psi^s)}$$

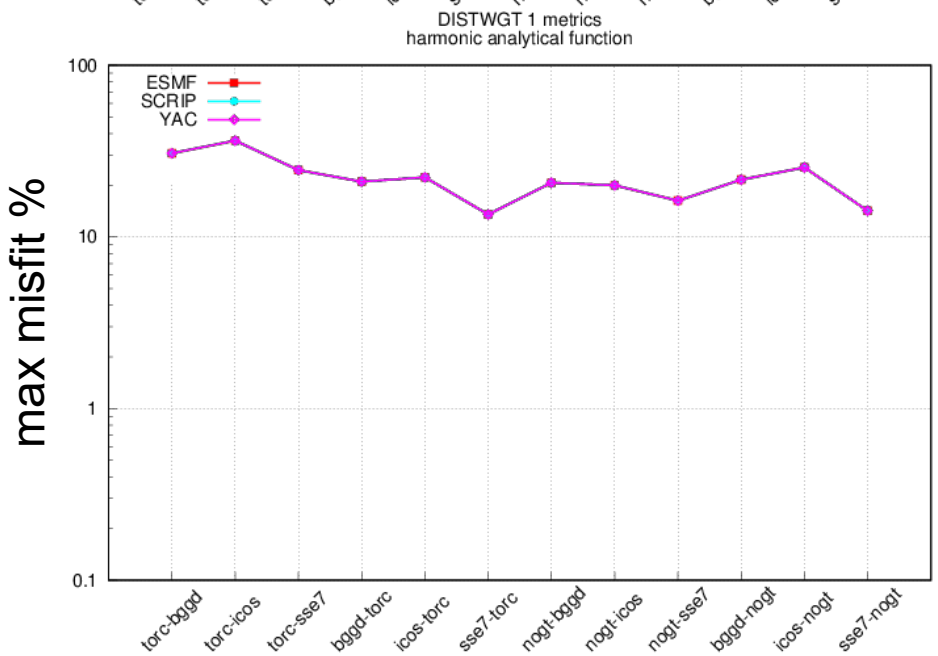
- monotonicity: preservation of global solution bounds
  - ✓ Lmin & Lmax

$$L_{\min} = \frac{\min\Psi^t - \min\mathbf{R}\Psi^s}{\max|\Psi^t|} \qquad L_{\max} = \frac{\max\mathbf{R}\Psi^s - \max\Psi^t}{\max|\Psi^t|}$$

- performances
  - ✓ Scalability curves on kraken (Cerfacs Lenovo)
- dissipation (over a back-and-forth exchange)

Benchmarking of regridding libraries – results DISTWGT

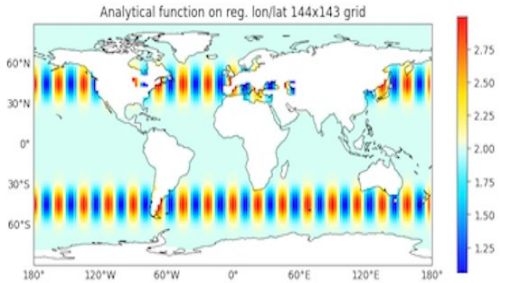




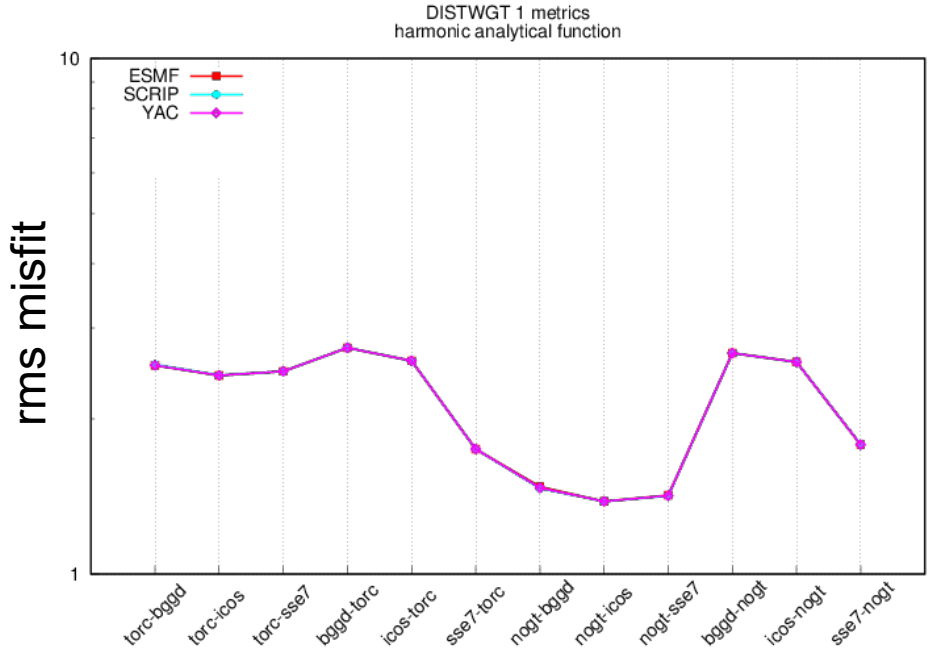
DISTWGT (nearest-neighbour)

harmonic

SCRIP, ESMF, YAC (not in XIOS)

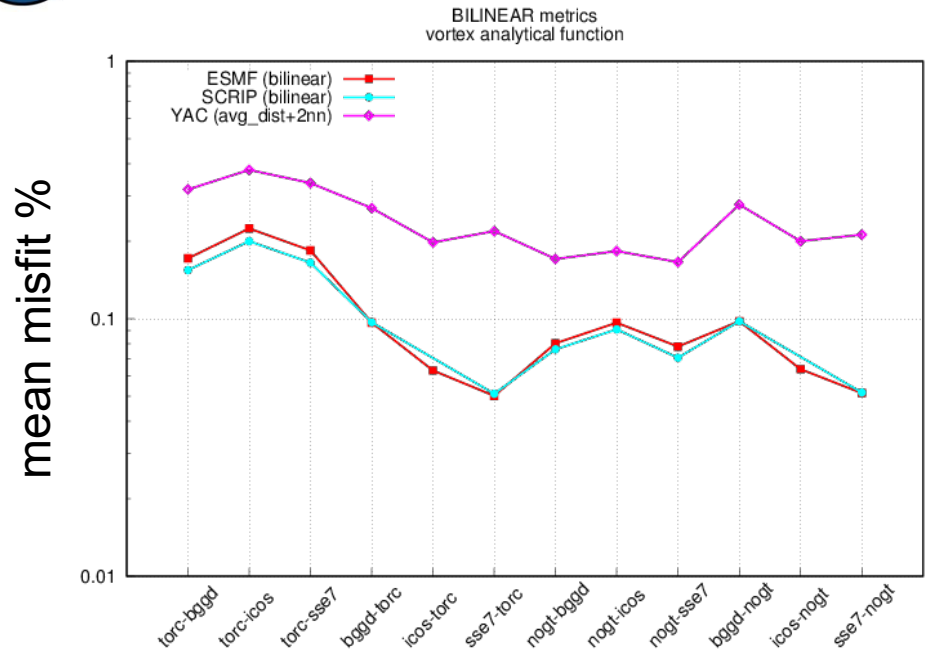


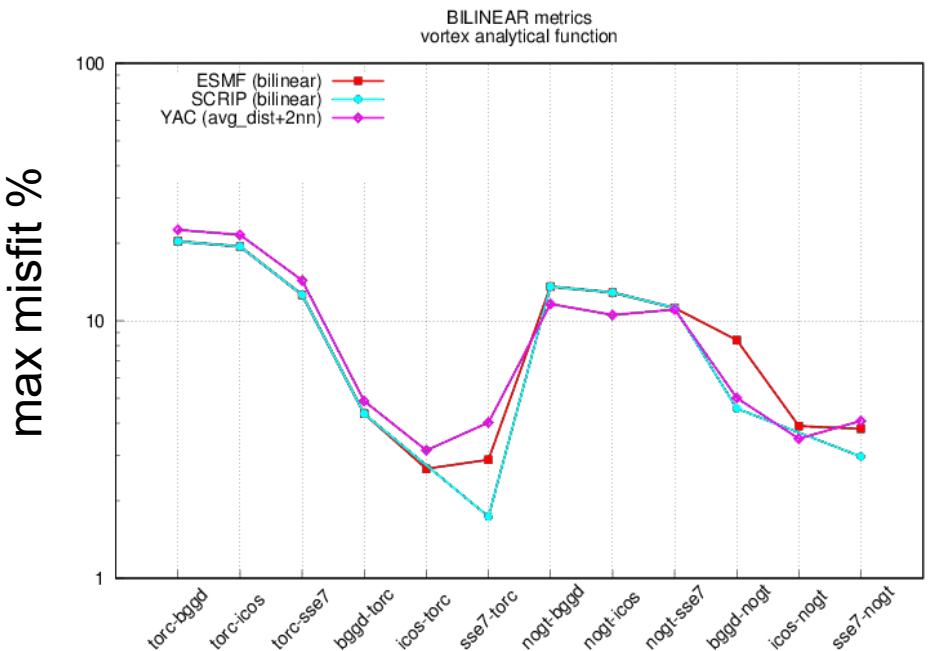
ESMF
SCRIP
YAC

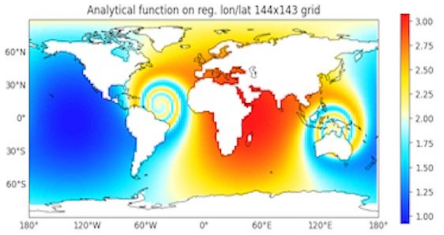


- SCRIP, ESMF & YAC produce same and reasonable results

Benchmarking of regridding libraries – results BILINEAR





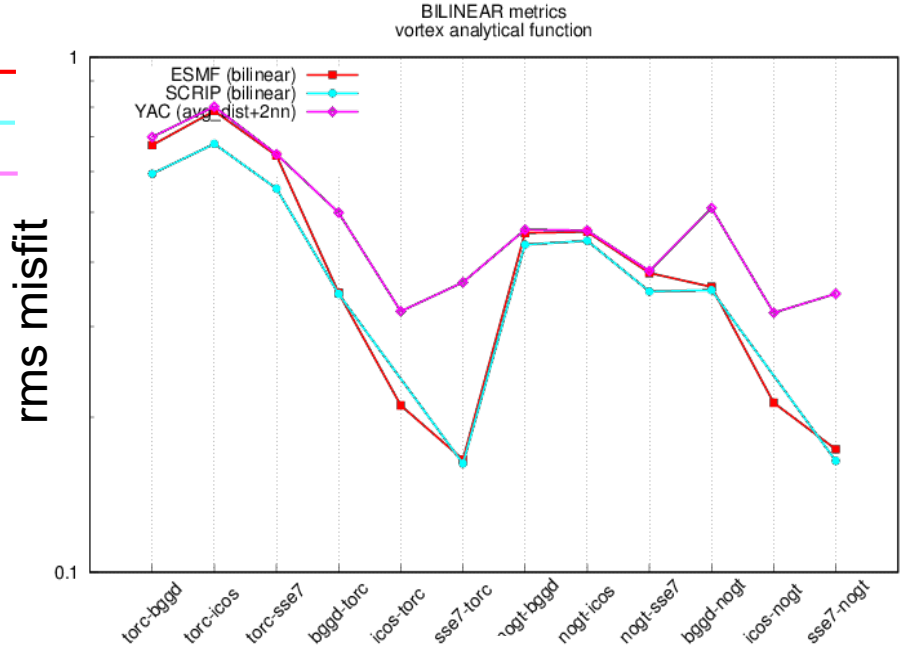


BILINEAR

vortex

SCRIP, ESMF, YAC (inverse distance weighting of enclosing neighbours) (not in XIOS)

ESMF
SCRIP
YAC

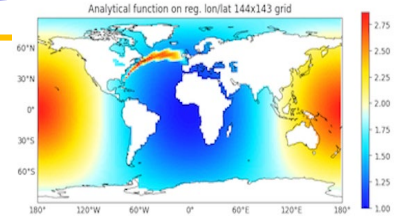


➢YAC less accurate on average

Benchmarking of regridding libraries – results 2nd ORDER

$$L_{\min} = \frac{\min \Psi^t - \min \mathbf{R}\Psi^s}{\max |\Psi^t|} \qquad L_{\max} = \frac{\max \mathbf{R}\Psi^s - \max \Psi^t}{\max |\Psi^t|}$$

Lmin/Lmax positive => under/overshoots
Lmin/Lmax negative => smoothing



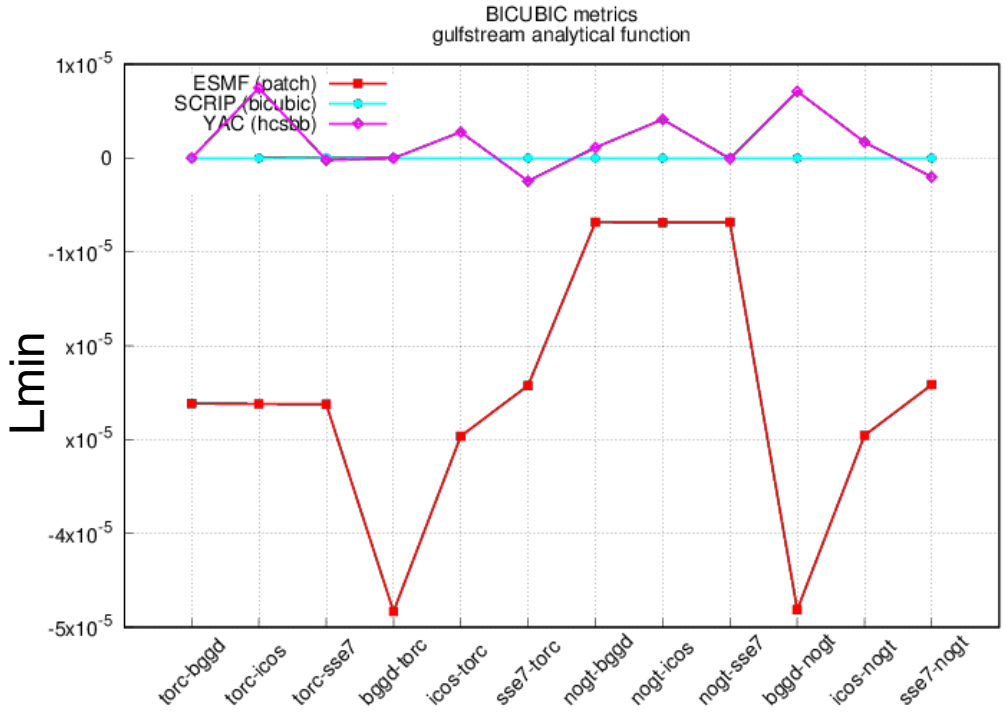
BICUBIC, PATCH, HCSBB

gulfstream

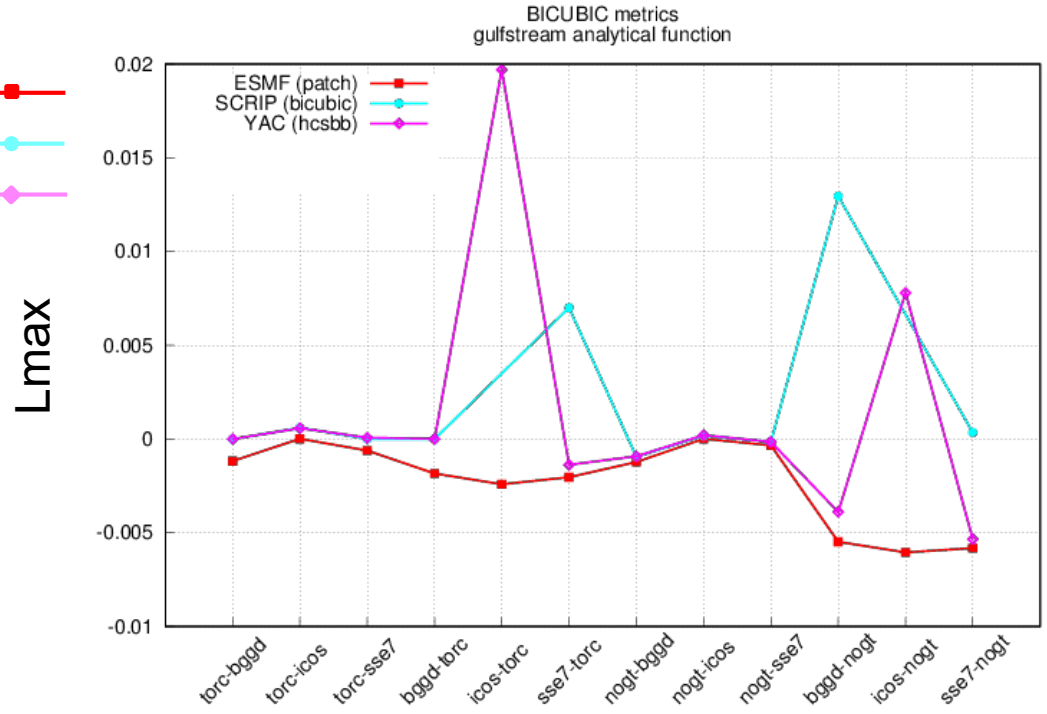
SCRIP (local-coordinate system bicubic approx, Jones 1999)

ESMF (multiple 2nd deg 2D polynomial source patches)

YAC (spherical Bernstein-Bézier polynomials, Liu & Schumaker 1996) (not in XIOS)

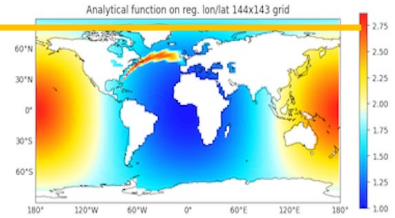


ESMF
SCRIP
YAC



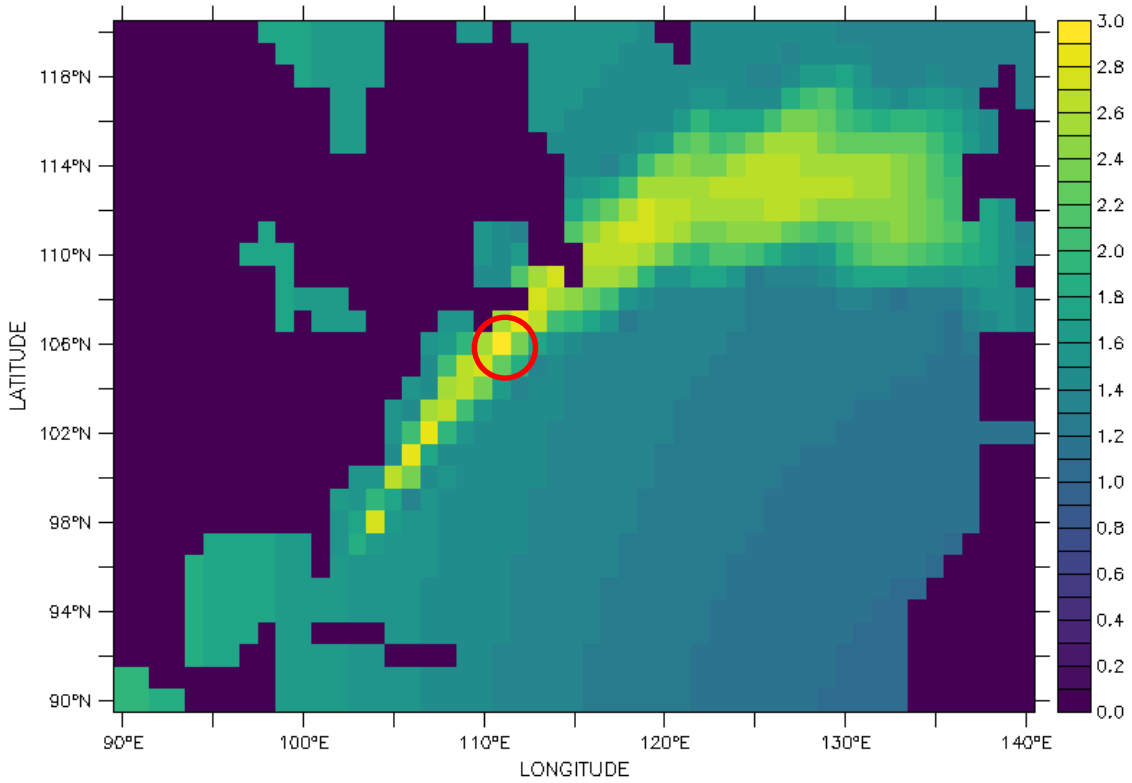
- ESMF smooths function minimum
- YAC "overshoots" when source grid is icosahedral (icos-torc & icos-nogt)

Benchmarking of regridding libraries – results 2nd ORDER



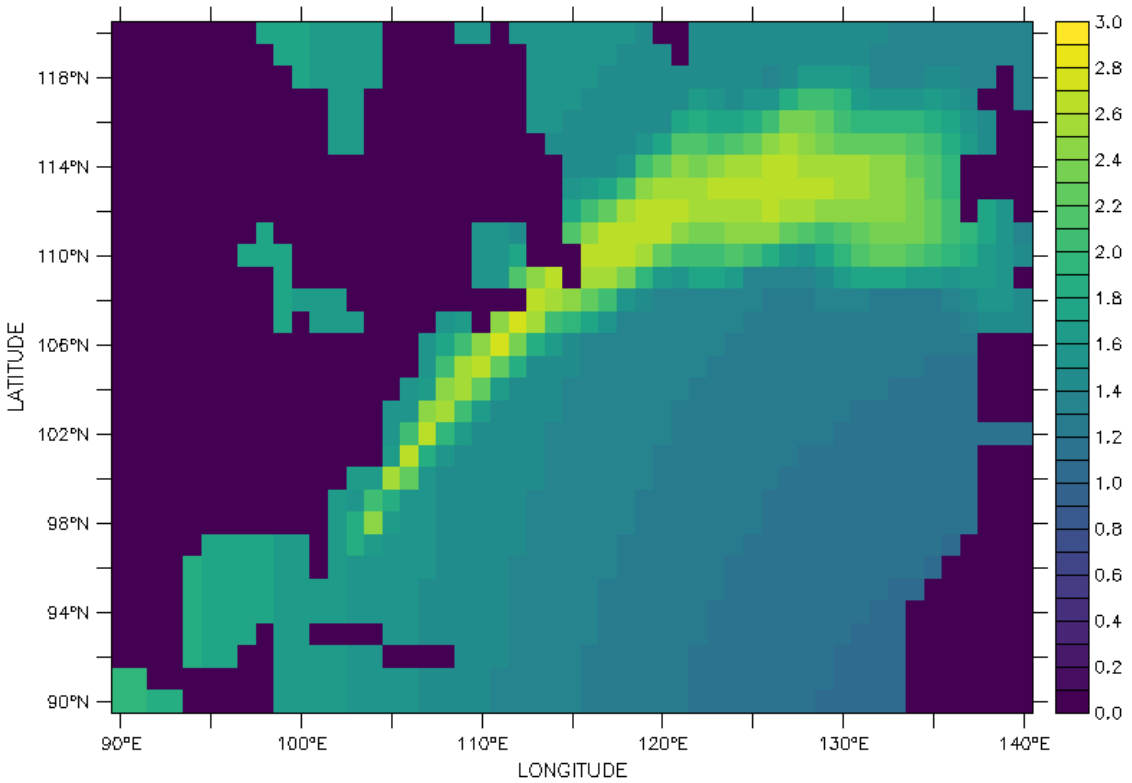
2nd ORDER, gulfstream, icos->torc

YAC HCSBB



regridded field

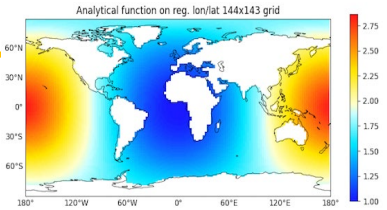
ESMF PATCH



regridded field

➢ YAC: higher, but not anomalous, values in the centre of the gulfstream (“overshoot”)

Benchmarking of regridding libraries – CONSERV 1st ORDER



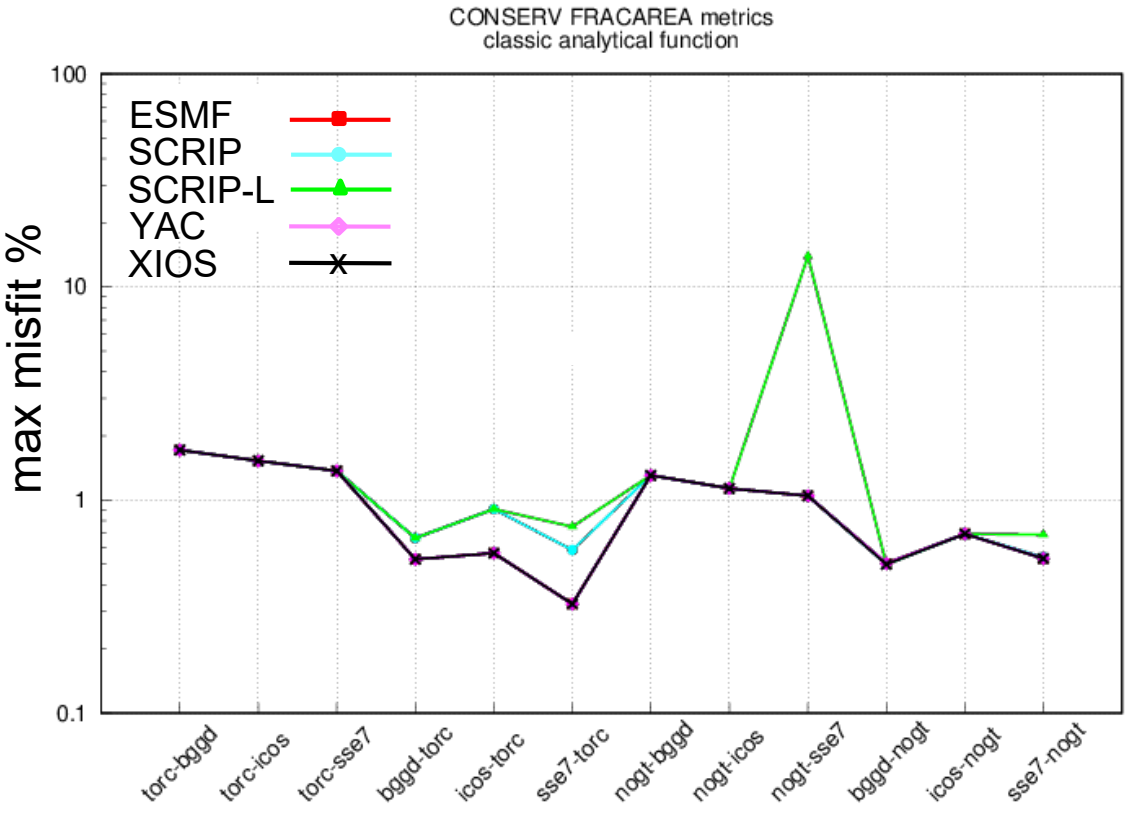
FRACAREA: if non-matching sea-land masks, normalisation with **intersected area** (sometimes cancels error)

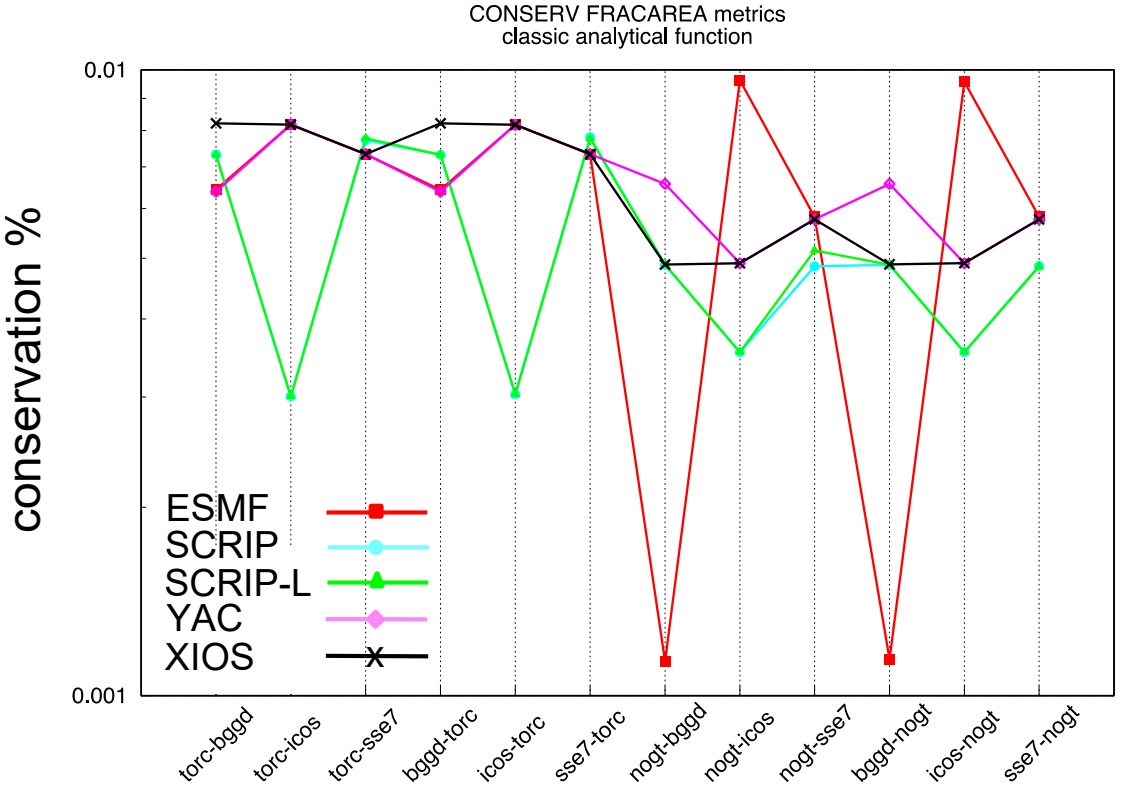
CONSERV 1st O (FRACAREA)

sinusoid

SCRIP, SCRIP-L (with Lambert proj. above 83 N)

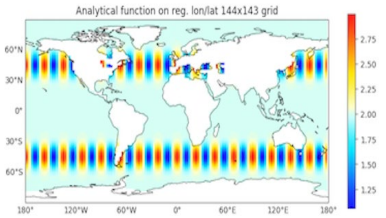
ESMF, YAC, XIOS





➢ Good conservation for ESMF, YAC & XIOS, problems for SCRIP-L (nogt<->sse7)

Benchmarking of regridding libraries – CONSERV 1st ORDER



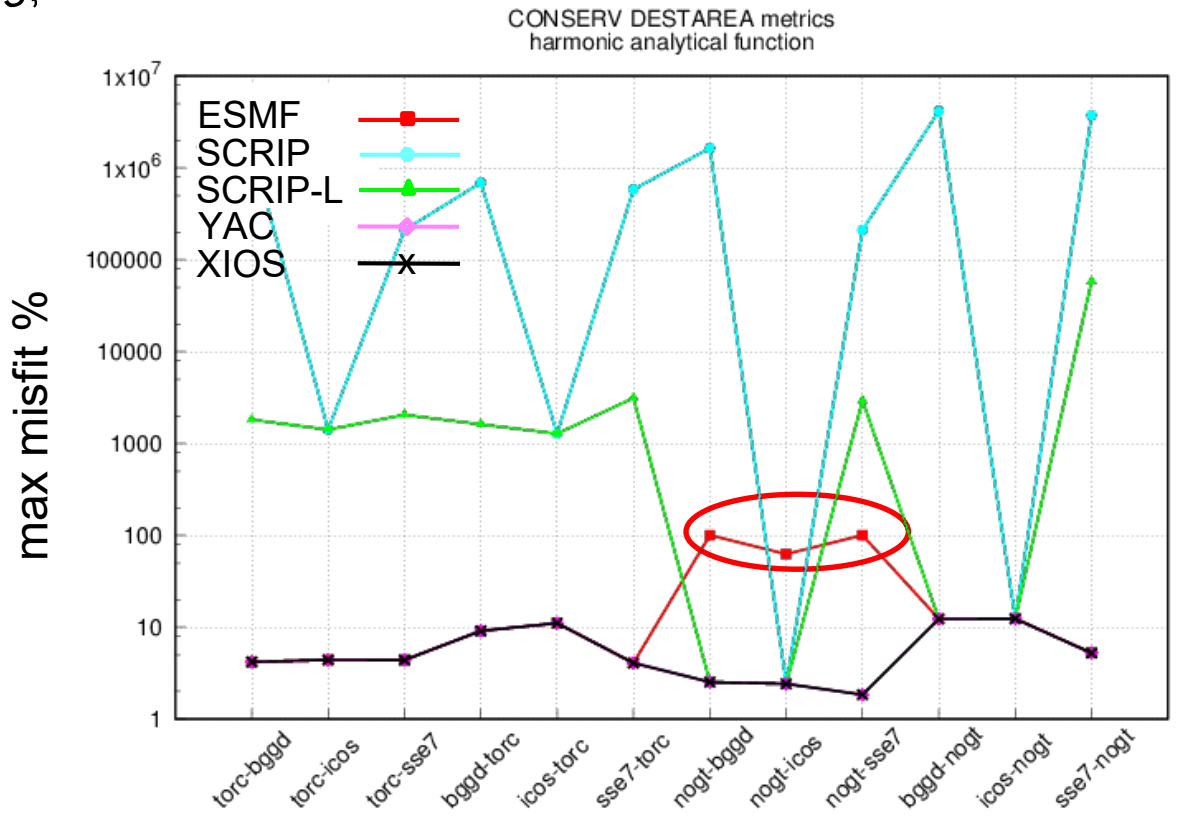
DESTAREA: if non-matching sea-land masks, normalisation with full target cell area (reveals errors, no cancellation)

CONSERV 1st O (DESTAREA)

harmonic

SCRIP, SCRIP-L (with Lambert proj. above 83 N)

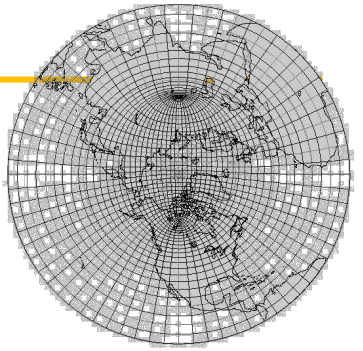
ESMF, YAC, XIOS



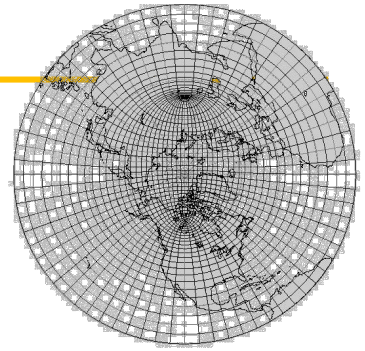
- Problems for SCRIP(-L); good similar results for XIOS, ESMF and YAC (Kritsikis et al 2017)
- Problems with NEMO North fold for ESMF when nogt **structured** is source

Benchmarking of regridding libraries – CONSERV 1st ORDER

CONSERV 1st O (DESTAREA) – harmonic – nogt->bggd

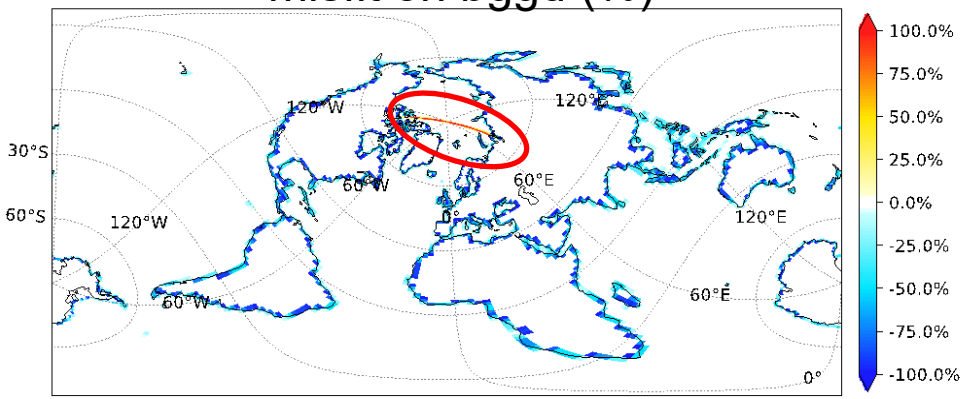


Benchmarking of regridding libraries - CONSERV 1st ORDER



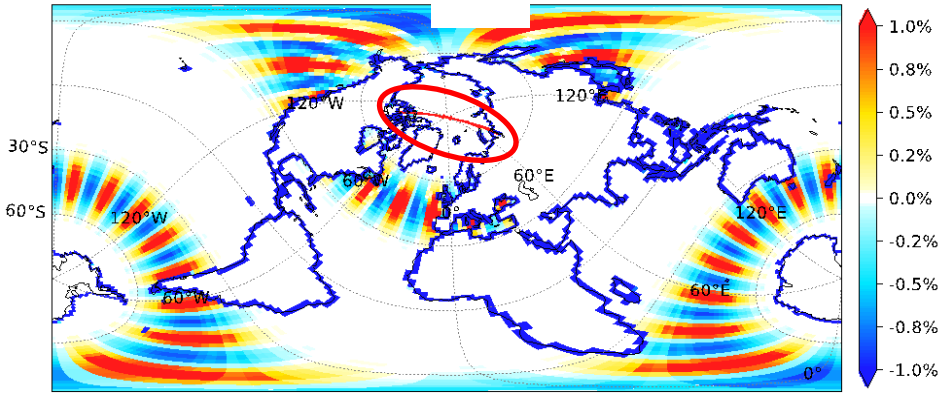
CONSERV 1st O (DESTAREA) – harmonic – nogt->bggd

misfit on bggd (%)

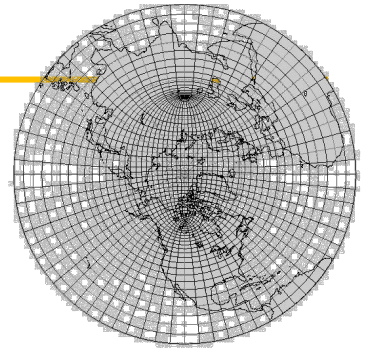


nogt NEMO ORCA1 ***structured***

misfit on bggd (%)

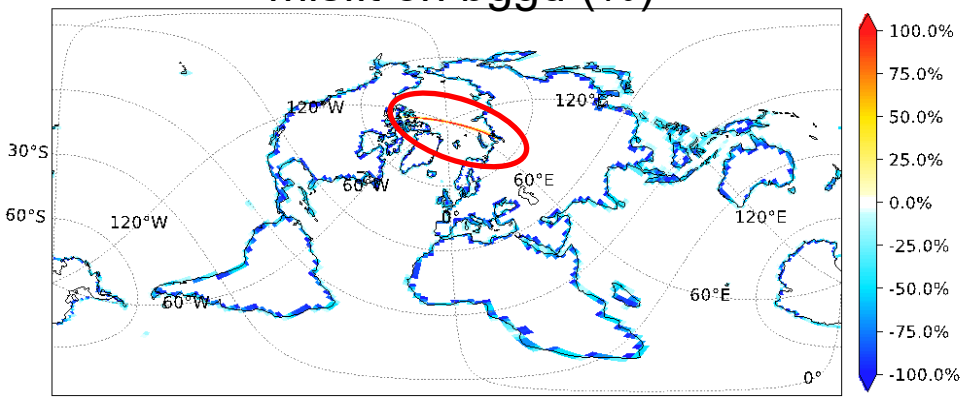


Benchmarking of regridding libraries – CONSERV 1st ORDER

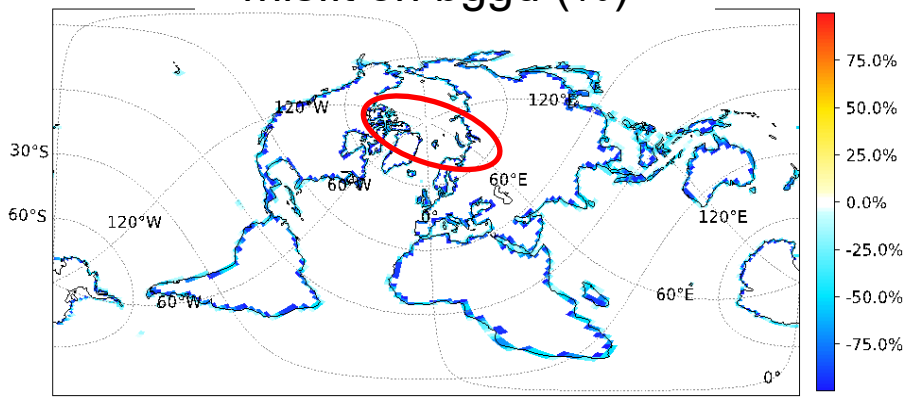


CONSERV 1st O (DESTAREA) – harmonic – nogt->bggd

misfit on bggd (%)

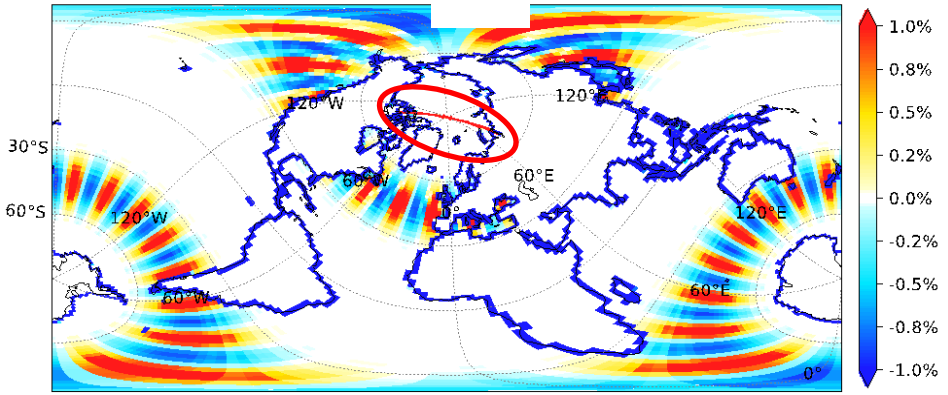


misfit on bggd (%)



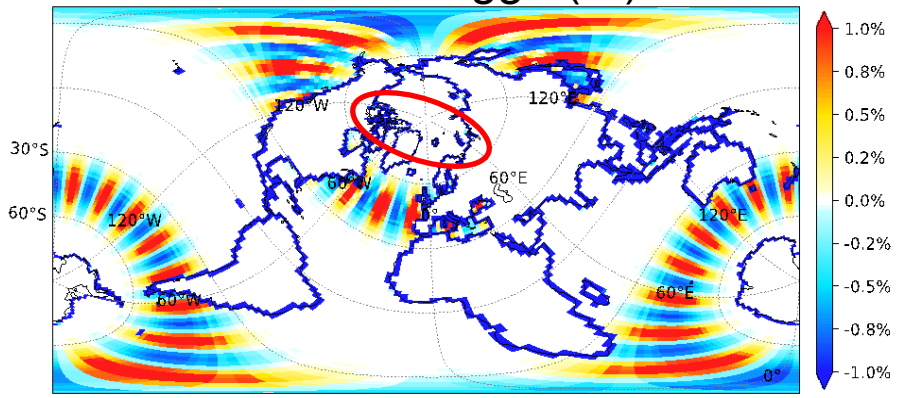
nogt NEMO ORCA1 ***structured***

misfit on bggd (%)



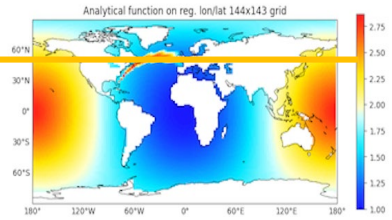
nogt NEMO ORCA1 ***unstructured***

misfit on bggd (%)



➢ Good results for ORCA grid North fold with ESMF if nogt is declared **unstructured**

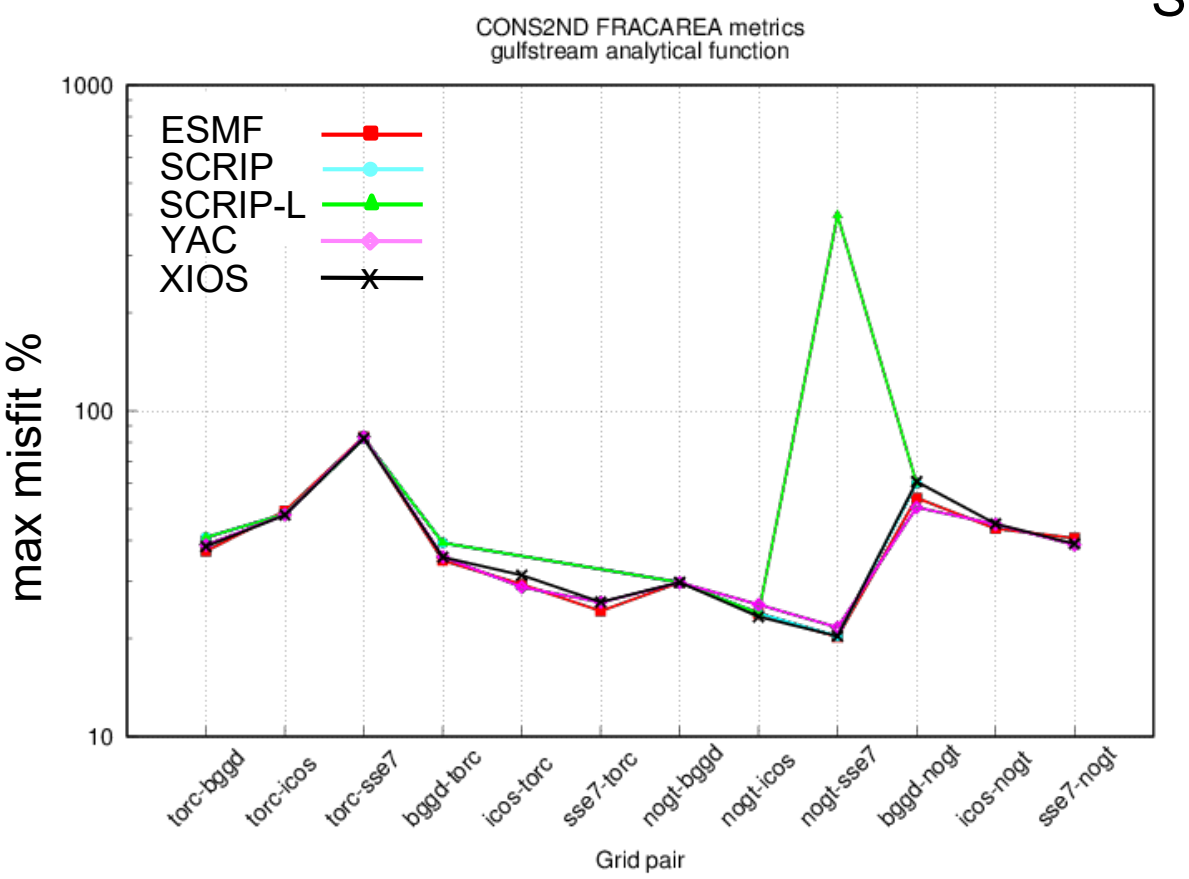
Benchmarking of regridding libraries – CONSERV 2nd ORDER

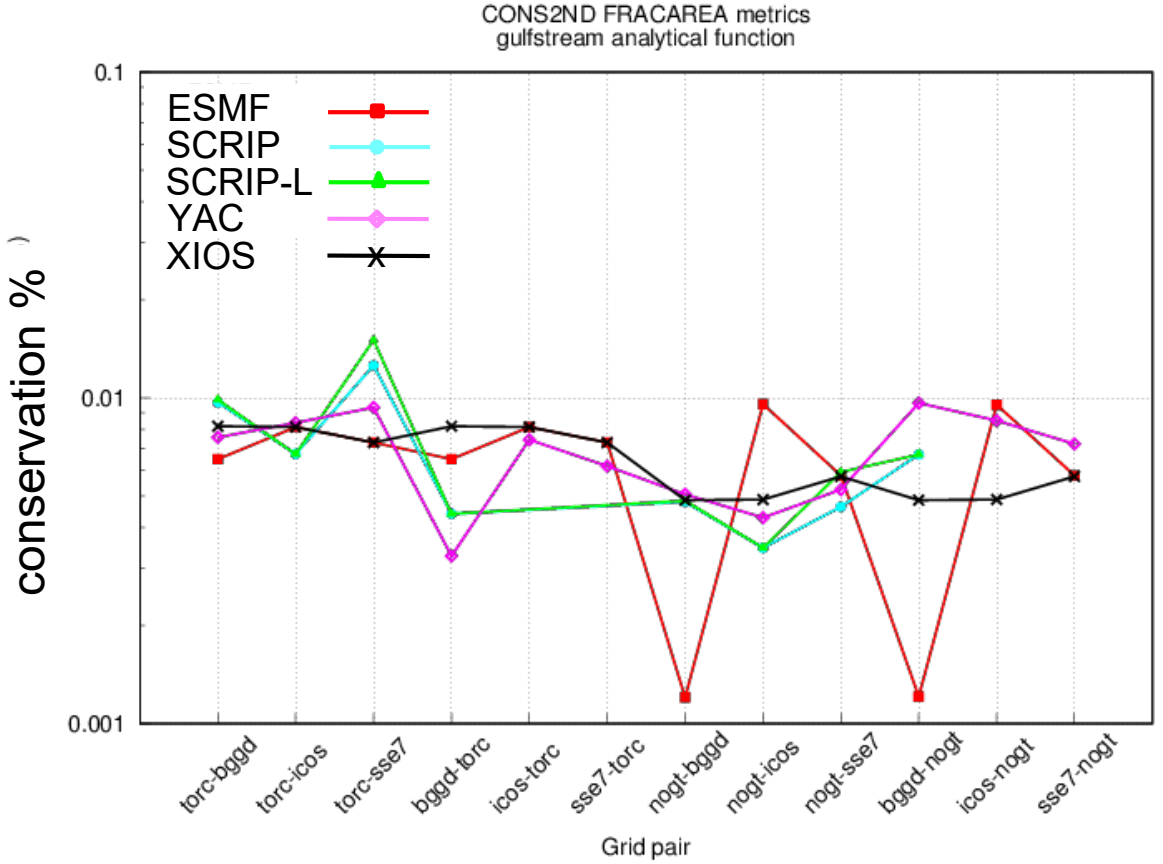


CONSERV 2nd O FRACAREA

gulfstream

SCRIP, SCRIP-L, ESMF, YAC, XIOS





- Good and similar results for XIOS, ESMF and YAC (Kritsikis et al 2017)
- Problems for SCRIP & SCRIP-L (in OASIS3-MCT) for nogt-sse7

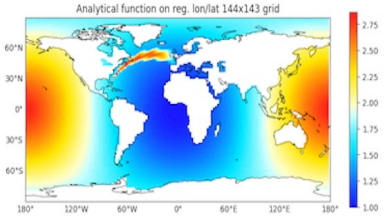
Benchmarking of regridding libraries – CONSERV 2nd ORDER

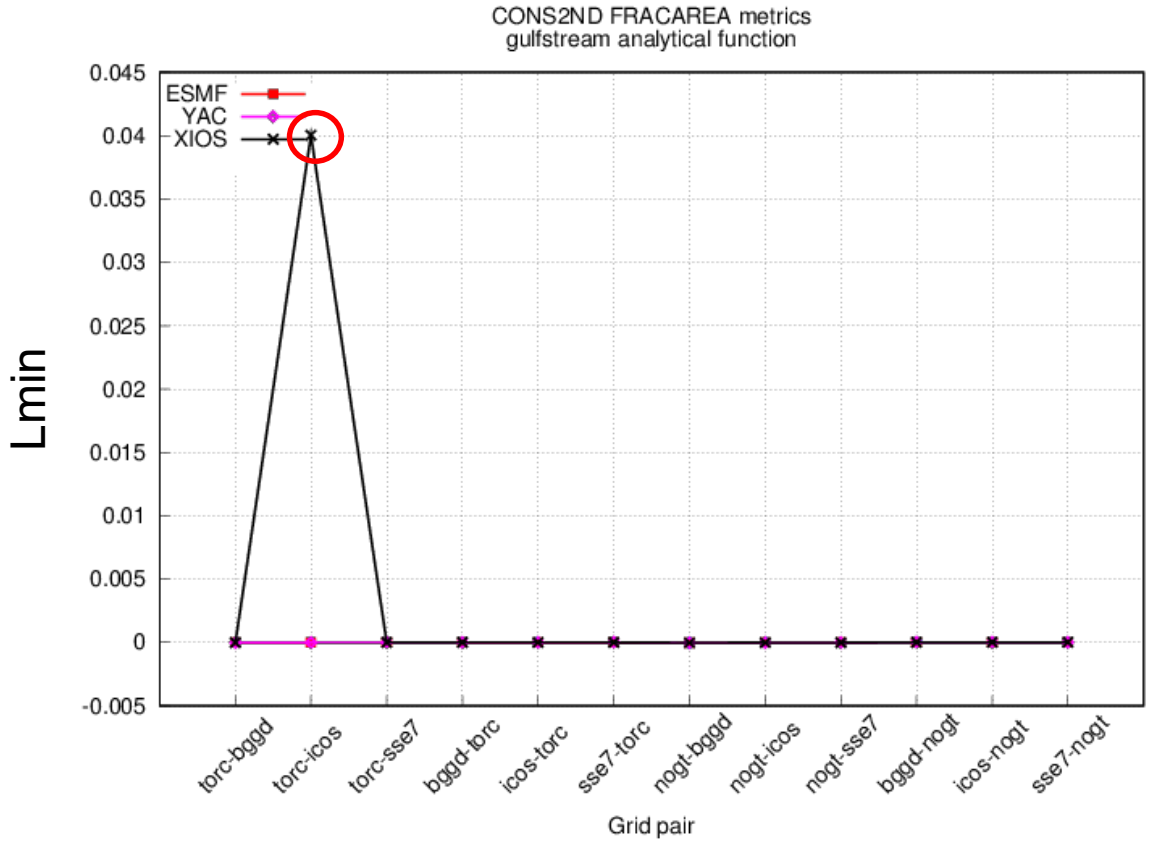
$$L_{\min} = \frac{\min \Psi^t - \min \mathbf{R}\Psi^s}{\max |\Psi^t|} \qquad L_{\max} = \frac{\max \mathbf{R}\Psi^s - \max \Psi^t}{\max |\Psi^t|}$$

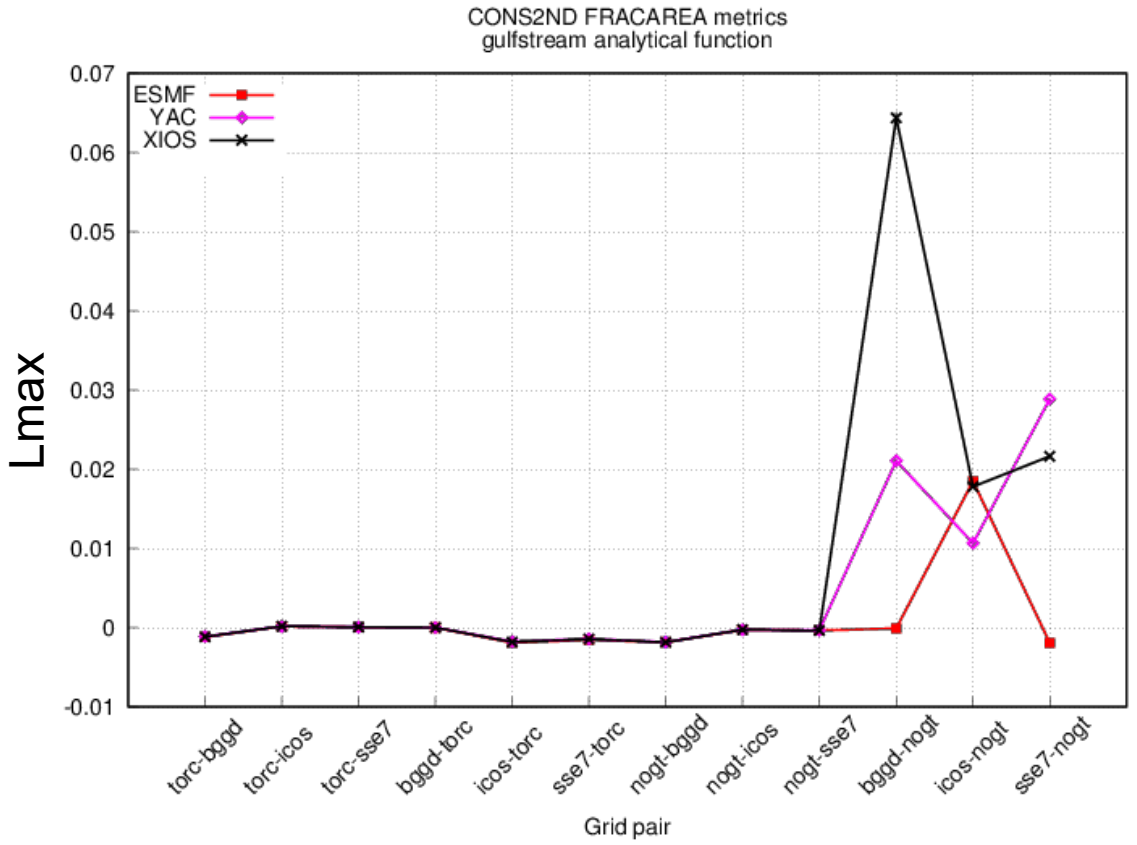
Lmin/Lmax positive => under/overshoots
Lmin/Lmax negative => smoothing

CONSERV 2nd O FRACAREA

gulfstream
ESMF, YAC, XIOS

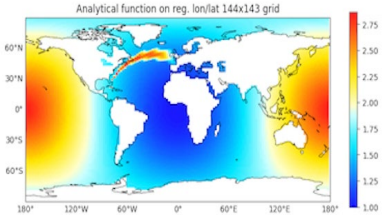




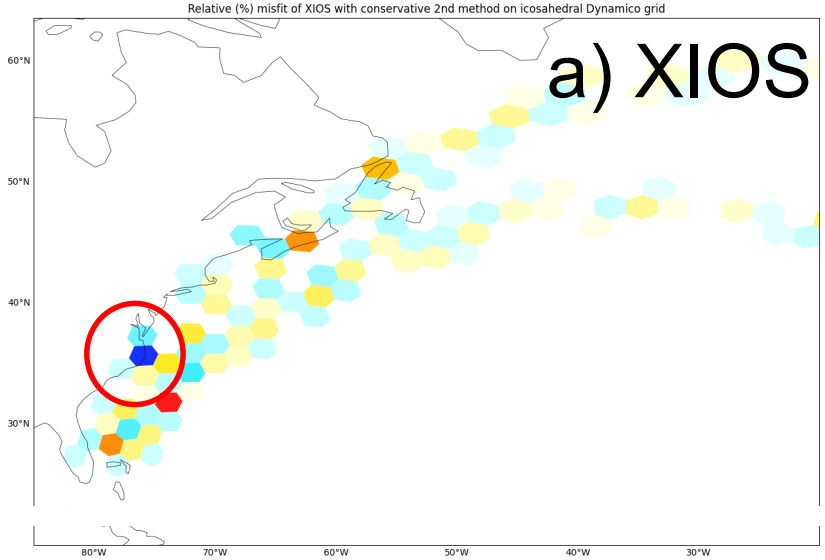


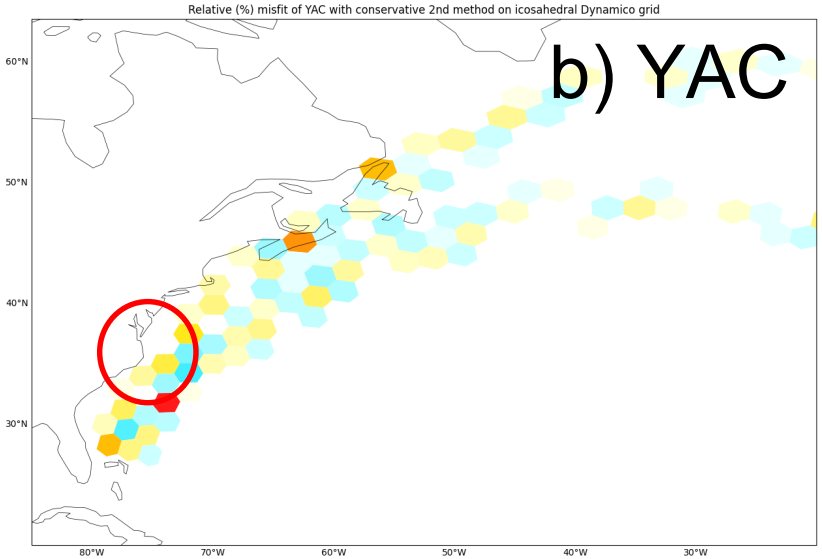
➢ XIOS undershoots for torc-icos and overshoots for bggd-nogt

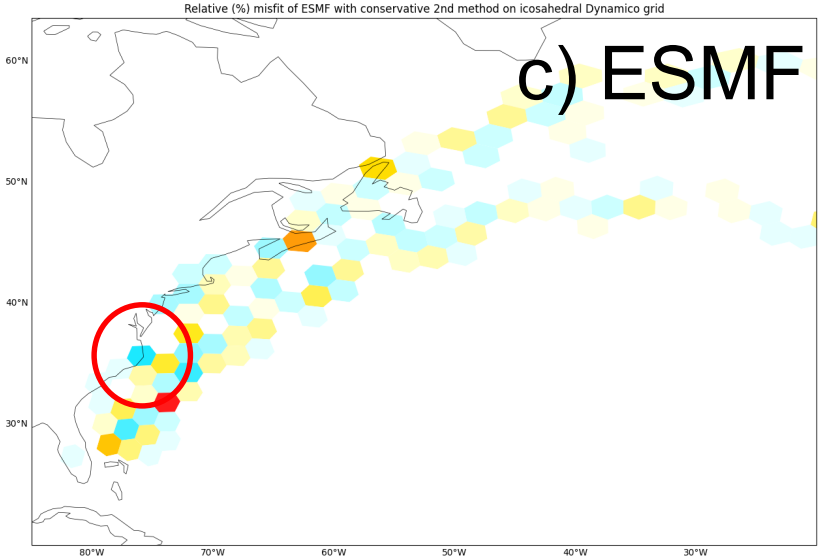
Benchmarking of regridding libraries – CONSERV 2nd ORDER

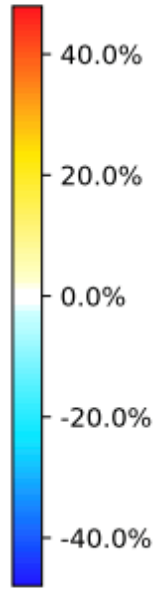


CONSERV 2nd O FRACAREA, qulfstream torc -> icos









➢XIOS undershoots for one point near the coast

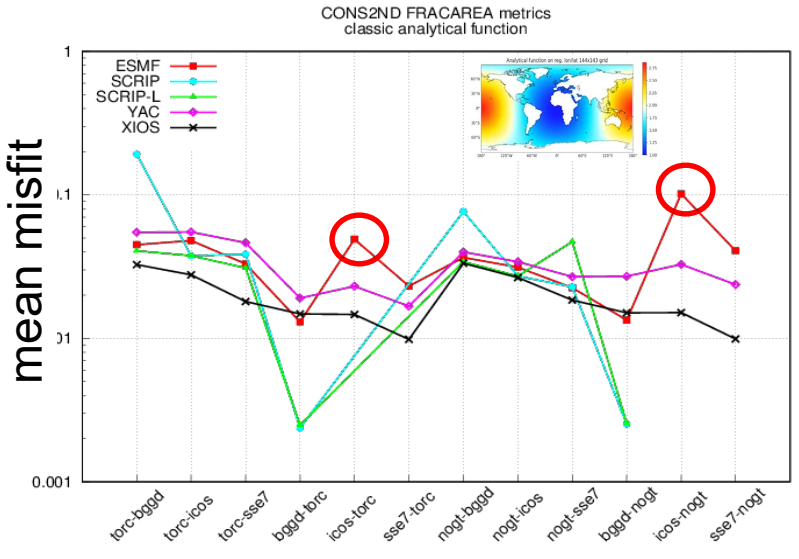
Benchmarking of regridding libraries – CONSERV 2nd ORDER

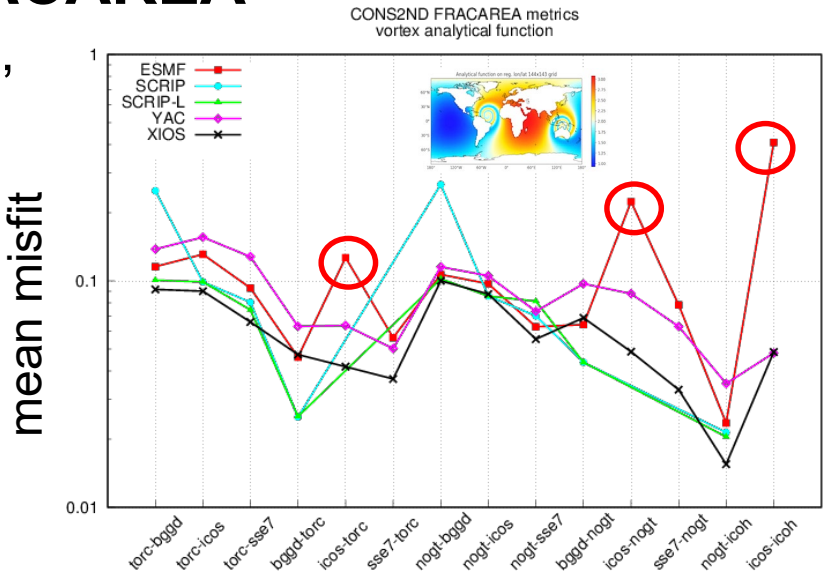
CONSERV 2nd O FRACAREA

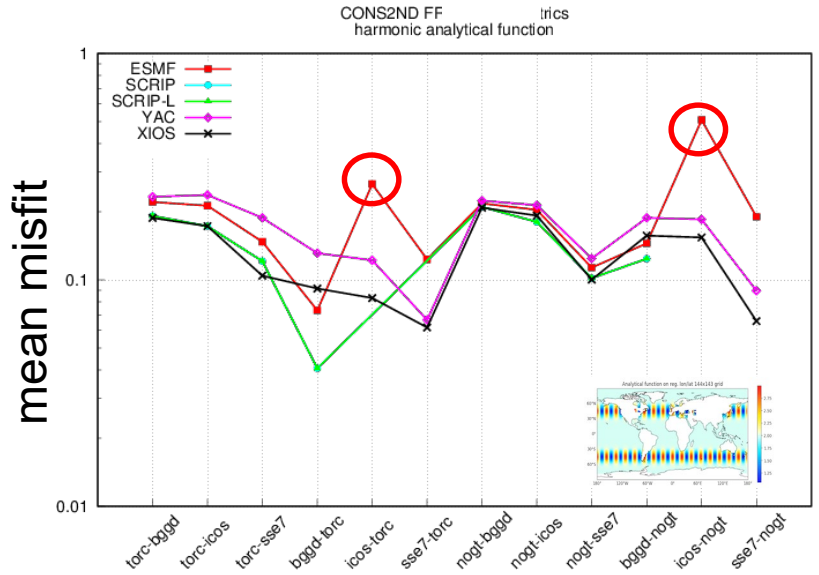
sinusoid, harmonic, vortex, gulfstream

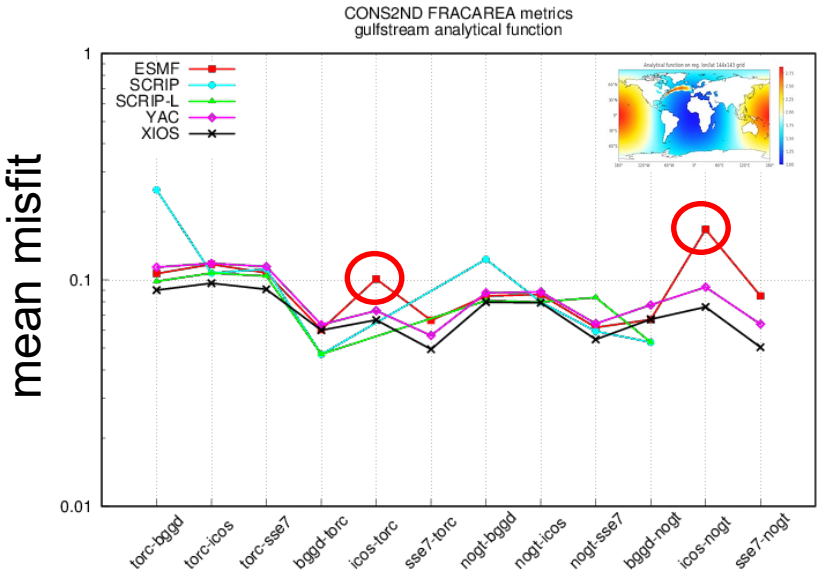
SCRIP, SCRIP-L, ESMF, YAC, XIOS

mean misfit









- high mean misfit with ESMF when icosahedral is source.
- working on it with ESMF support!

Benchmarking of regridding libraries – CONSERV 2nd ORDER

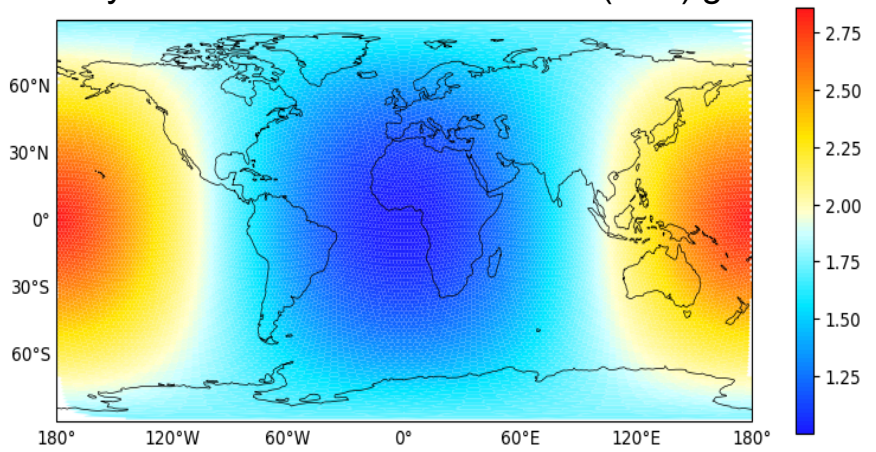
CONSERV 2nd O FRACAREA

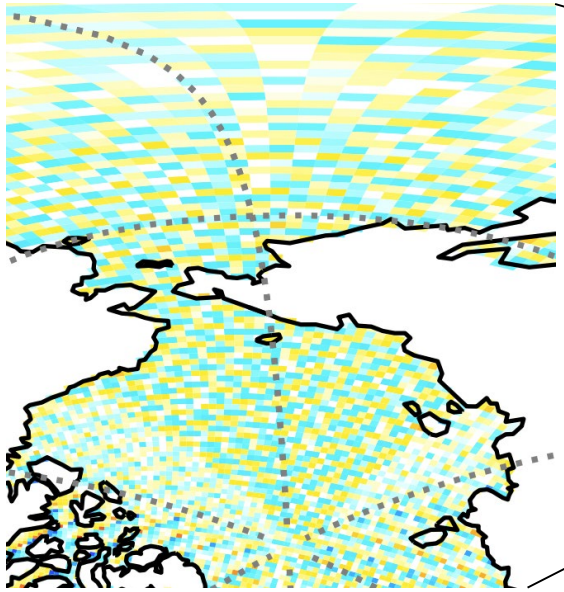
sinusoid

icos->nogt (icosahedral -> NEMO ORCA2)

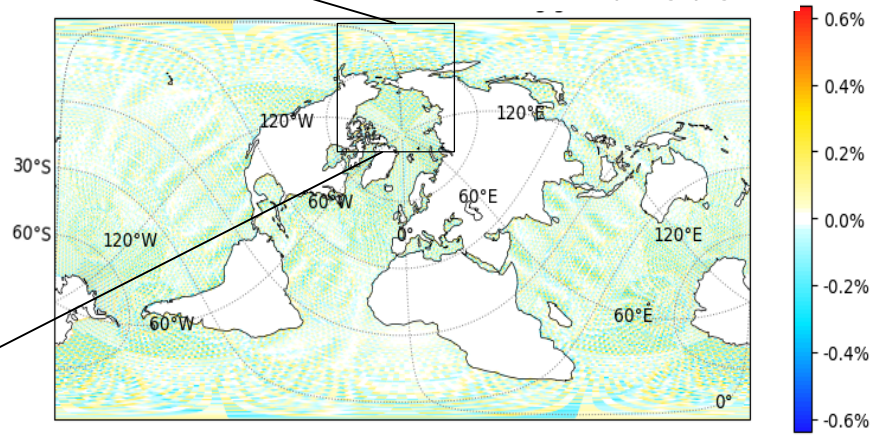
ESMF

Analytical sinusoid on icosahedral (icos) grid



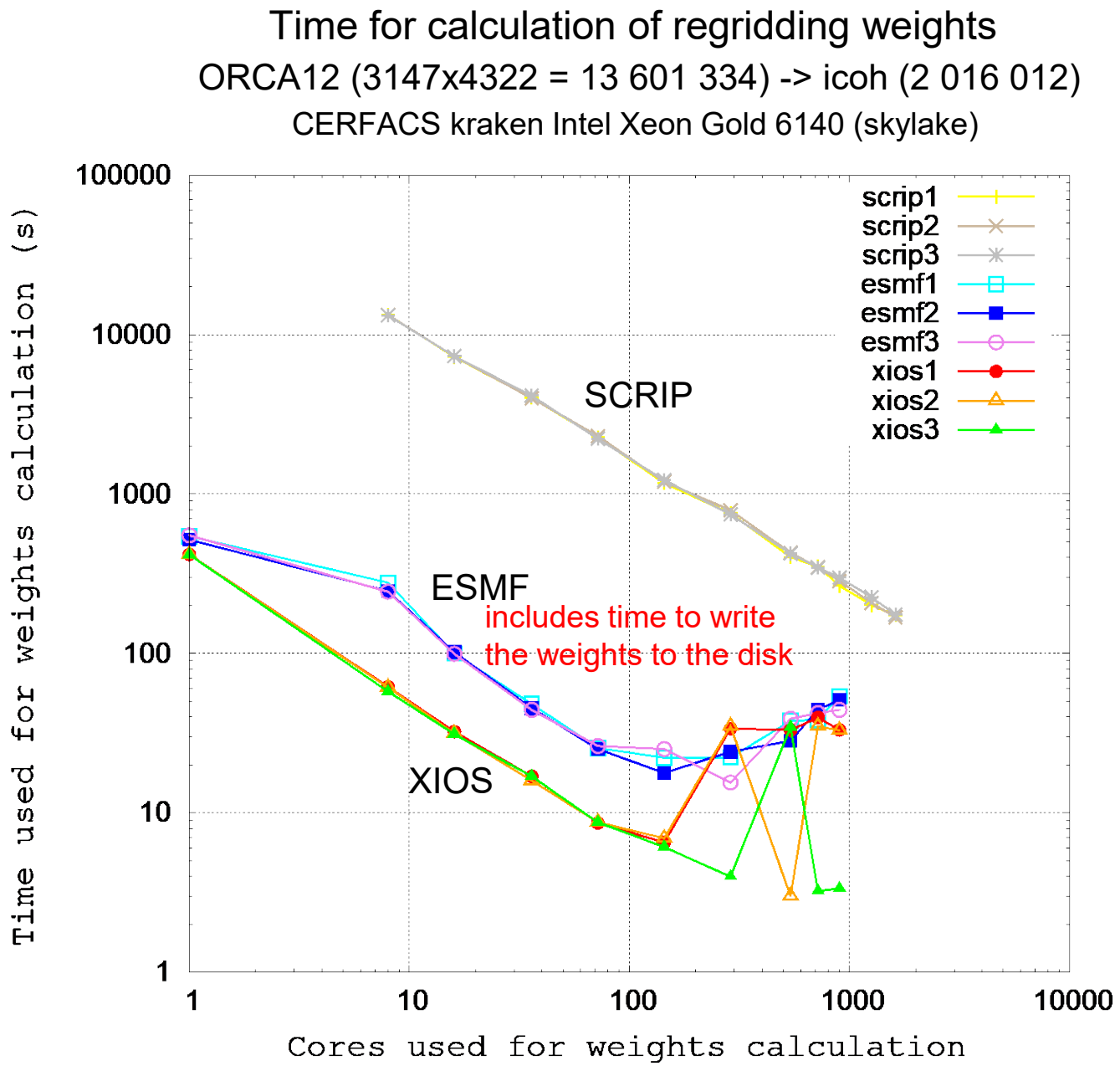


Relative misfit on NEMO ORCA2 (nogt) grid



➢ alternating + and – pattern with ESMF; working on it with ESMF support!

Benchmarking of regridding libraries – performance and scalability



- ESMF and XIOS show good performances (much more than the SCRIP)
- XIOS shows unstable behaviour for more than ~200 cores (to be investigated)
- On-line regridding for dynamic grids is becoming an option even for high-resolution coupled models

Benchmarking of regridding libraries – Conclusions

Technically

- Besides few details, under discussion with library developers, ESMF, YAC and XIOS provide high-quality regridding
- Good performance for ESMF and XIOS (much faster than the SCRIP); computing weights is the compute-intensive part of couplers -> dynamic high-res grids ? -> porting to GPUs ?

  - provide a unified environment to pre-calculate regridding weights with SCRIP, ESMF & XIOS in OASIS3-MCT_5.0 (12/2021)

Philosophically

Benchmarks help not so much to compare libraries but more to identify specific problems and solve them through interactions with developers!

With thanks to Bob, Moritz and Yann !

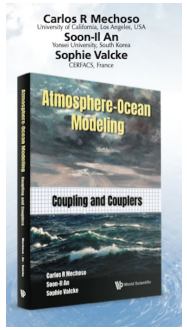
Jones, P. (1999) Conservative remapping: First- and second-order conservative remapping. Mon. Weather Rev., 127, 2204–2210.

Kritsikis, E., M. Aechtner, Y. Meurdesoif, and T. Dubos, 2017: Conservative interpolation between general spherical meshes, *Geosci. Model Dev.*, **10,** 425–431, https://doi.org/10.5194/gmd-10-425-2017

Hanke, M, and R. Redler, New features with YAC 1.5.0, https://doi.org/10.5676/DWD_pub/nwv/icon_003

Conclusions and perspectives

- OASIS3-MCT will most likely provides a satisfactory solution for fully parallel coupling in our climate models at the resolutions targeted operationally for the next ~5 years.
- On-going developments:
  - support for grids with dynamic masks
  - upgrade of compiling environment
  - new automated suite testing
  - environment for atmospheric mask definition based on ocean coastline
- Tests of coupling on GPUs (?)
- maintenance, active user support and training (SPOC) but probably no major evolution => in-kind contribution to ENES-RI of ~0.5 FTE
- Additional funding - TRACCS French national project (2024-2030, 6 PYs): further evolution and/or merging with XIOS



Mechoso, C. R., An, S. and Valcke, S (2021)
Atmosphere-Ocean Modelling - Coupling and Couplers. World Scientific., ISBN 978-9811232930

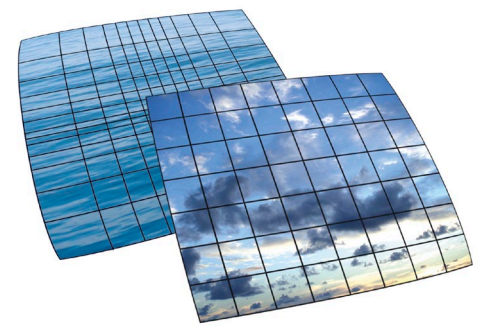
is-enes
INFRASTRUCTURE FOR THE EUROPEAN NETWORK FOR EARTH SYSTEM MODELLING

Oasis

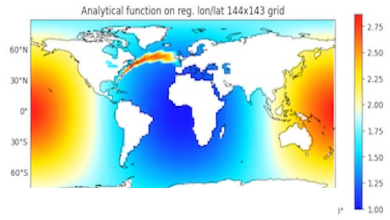
THE CONSORTIUM

Coordinated by **CNRS-IPSL**, the IS-ENES3 project gathers **22 partners** in **11 countries**

This project is funded by the European Union's Horizon 2020 research and innovation programme, grant agreement N°824084

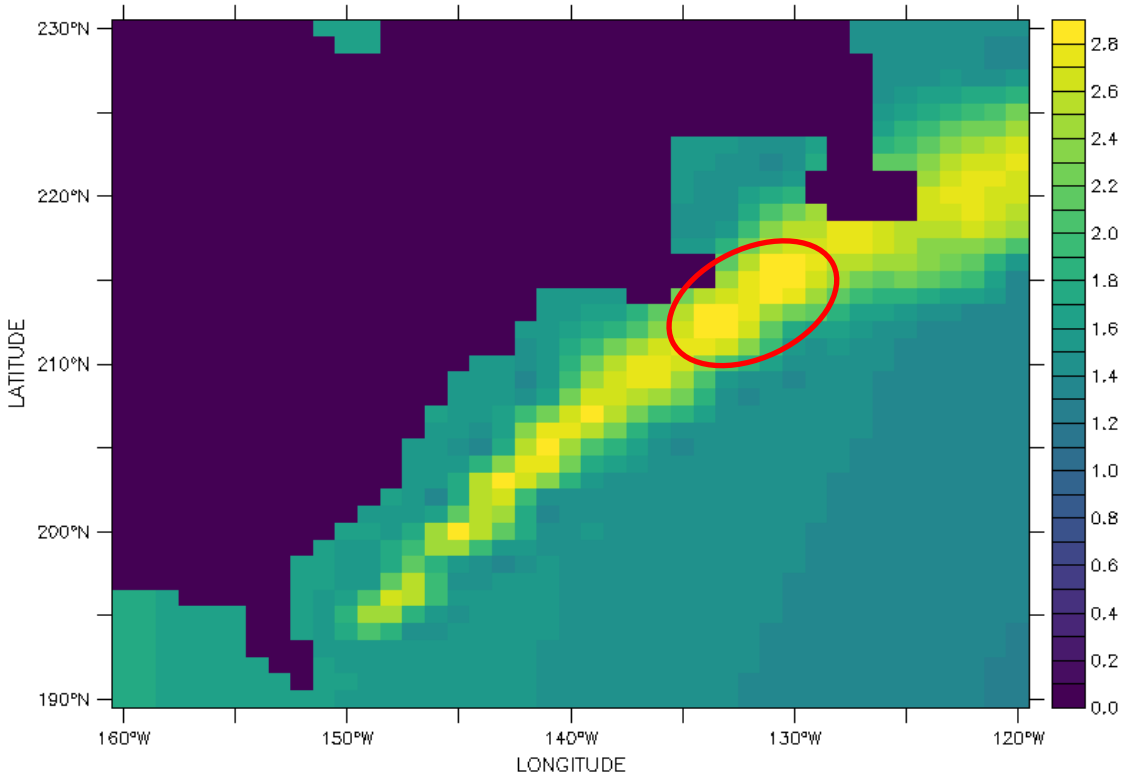


Regridding benchmark – results 2nd ORDER



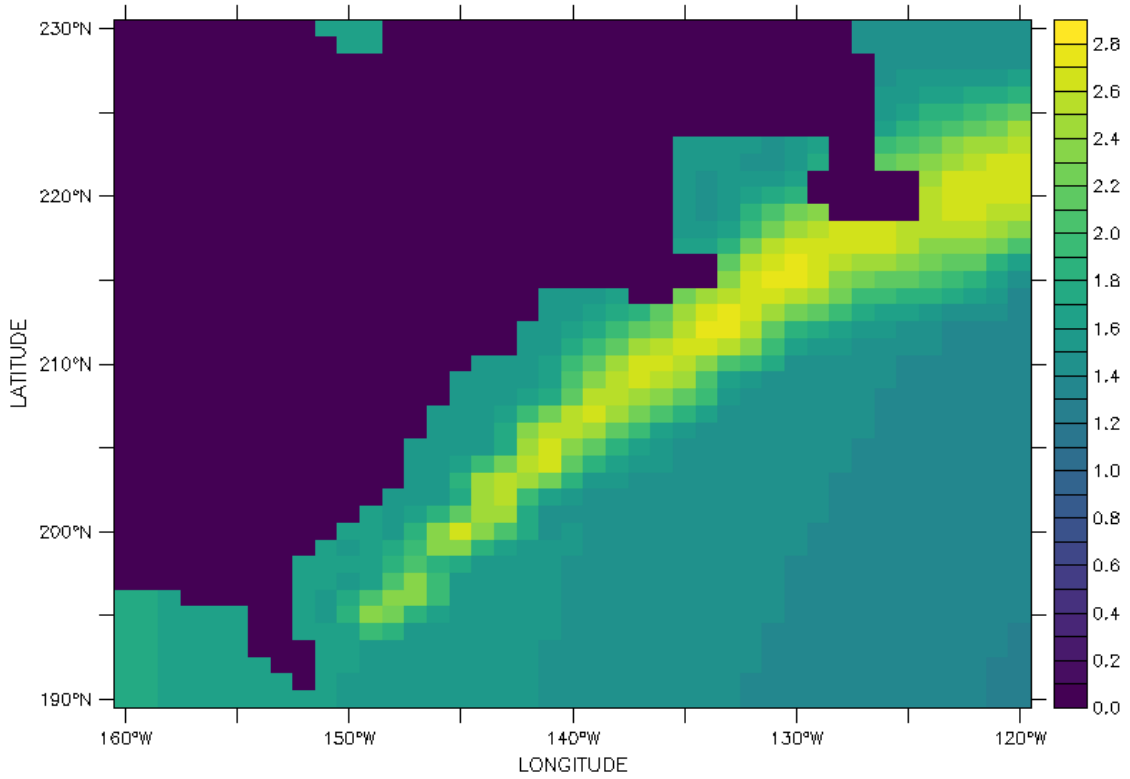
2nd ORDER, gulfstream, icos->nogt

YAC HCSBB



regridded field

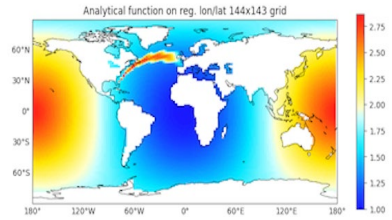
ESMF PATCH



regridded field

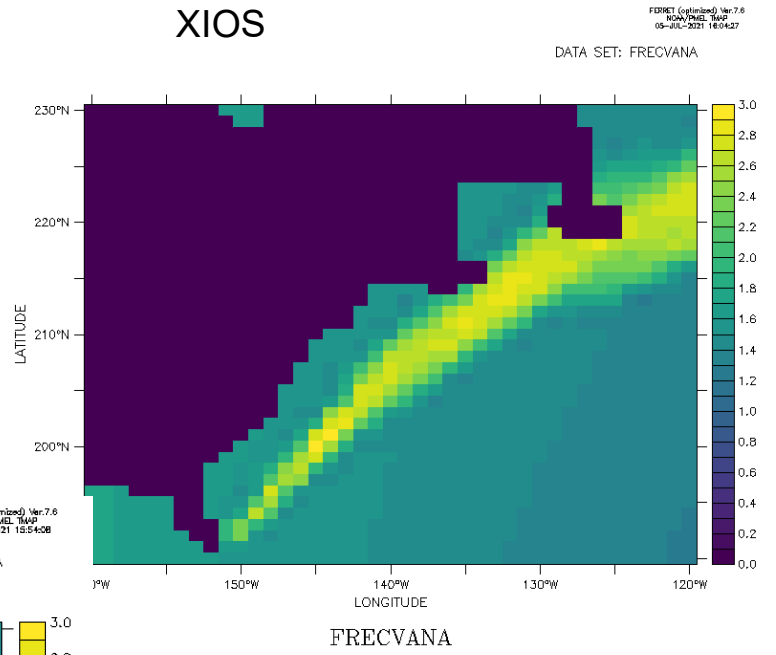
- YAC gives higher values in the centre of the gulfstream (“overshoot”)

Regridding benchmark –results CONSERV 2nd O

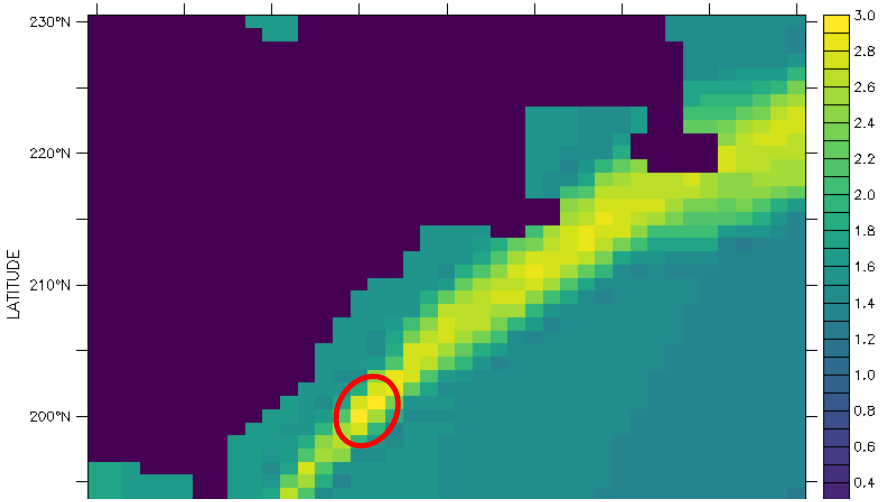


CONSERV 2nd O FRACAREA, gulfstream sse7 -> nogt

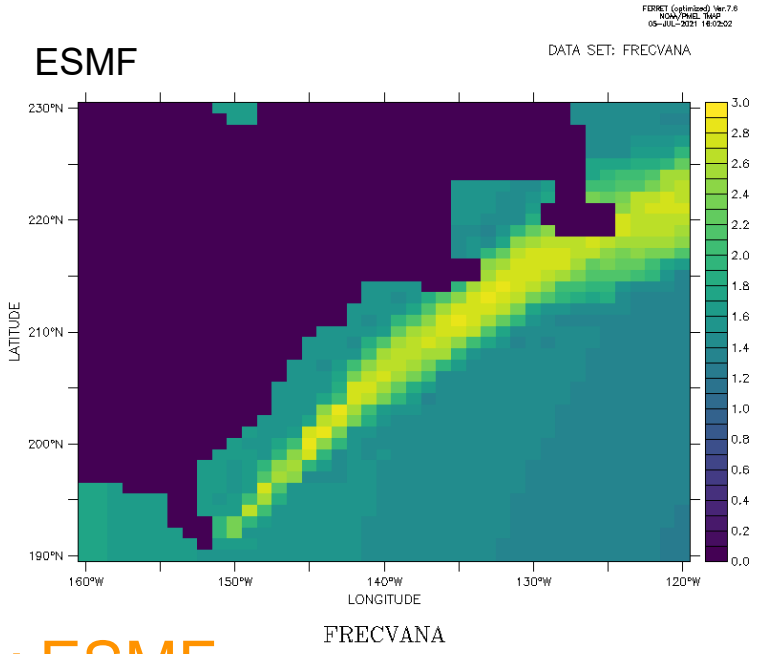
XIOS



YAC



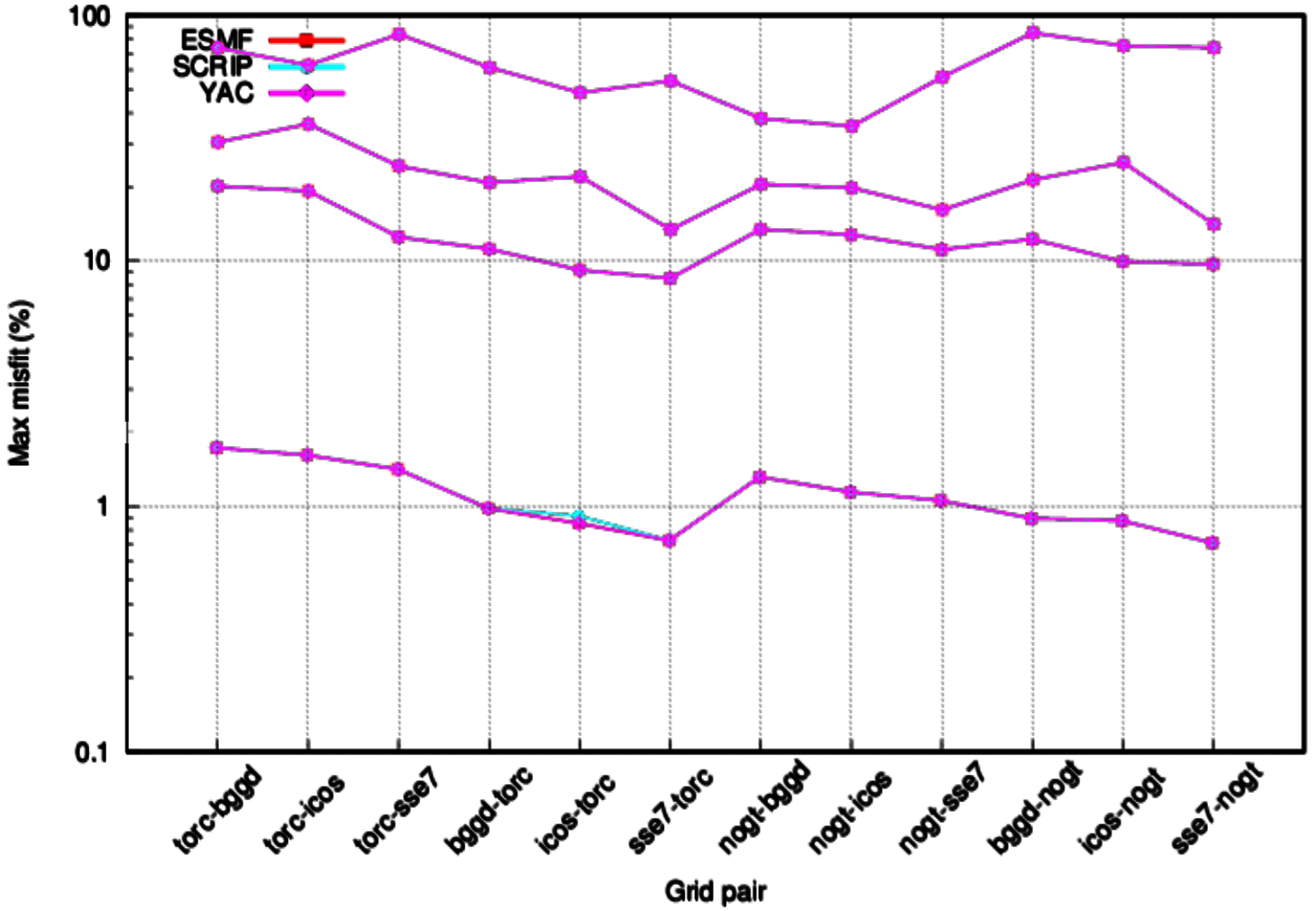
ESMF



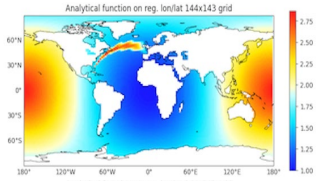
➢ Lmax YAC > Lmax XIOS >> Lmax ESMF

Regridding benchmark – results DISTWGT

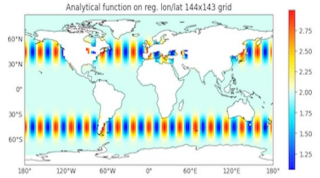
Impact of analytical function - DISTWGT



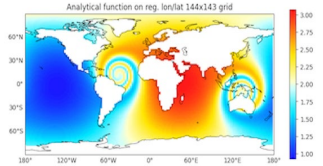
gulfstream



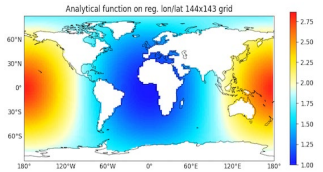
harmonic



vortex



sinusoid



➢ Strong impact of the analytical function chosen for regridding

is-enes
INFRASTRUCTURE FOR THE EUROPEAN NETWORK FOR EARTH SYSTEM MODELLING

IS-ENES3

January 2019 – December 2022

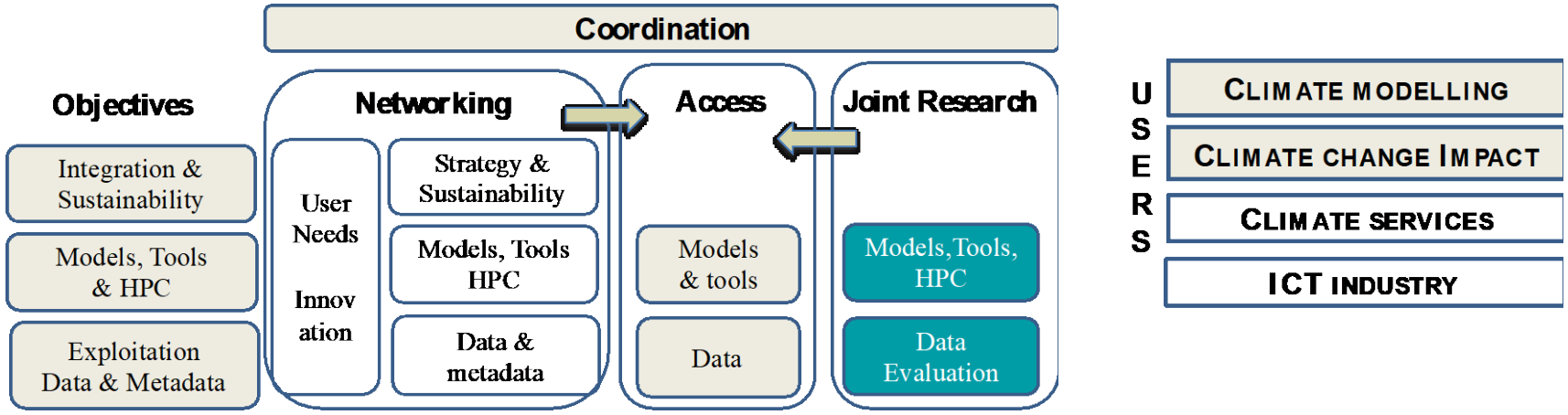
22 partners from 11 countries

THE CONSORTIUM

Coordinated by **CNRS-IPSL**, the IS-ENES3 project gathers **22 partners** in **11 countries**

3 main objectives:

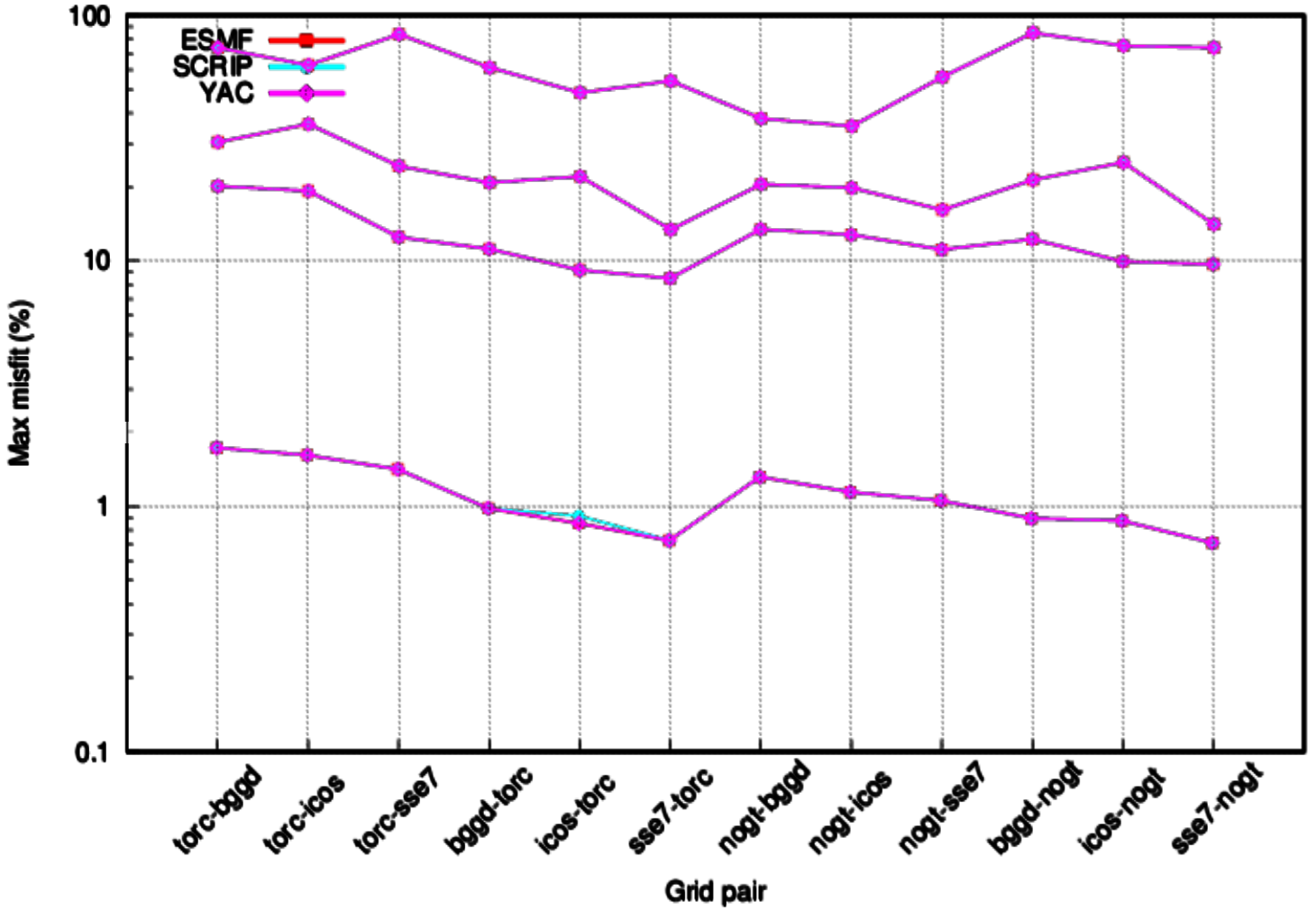
- Pursue the integration of the climate modelling community & ensure the sustainability of the research infrastructure
- Foster common development of models and tools and efficient use of HPC
- Support exploitation of model data by the Earth system science, the climate change impact and the climate service communities



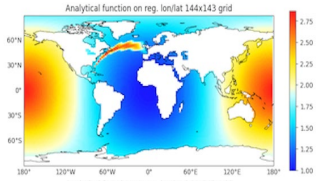
The IS-ENES3 project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824084

Regridding benchmark – results DISTWGT

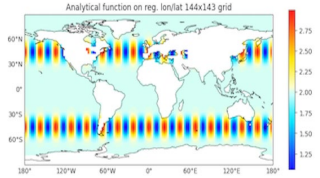
Impact of analytical function - DISTWGT



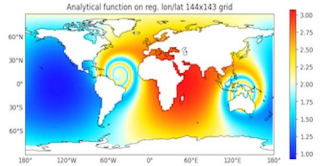
gulfstream



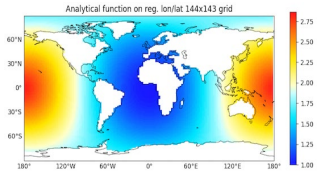
harmonic



vortex

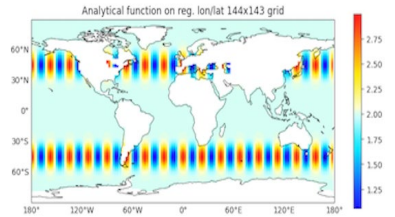


sinusoid



➢ Strong impact of the analytical function chosen for regridding

Regridding benchmark – results 2nd ORDER



BICUBIC, PATCH, HCSBB

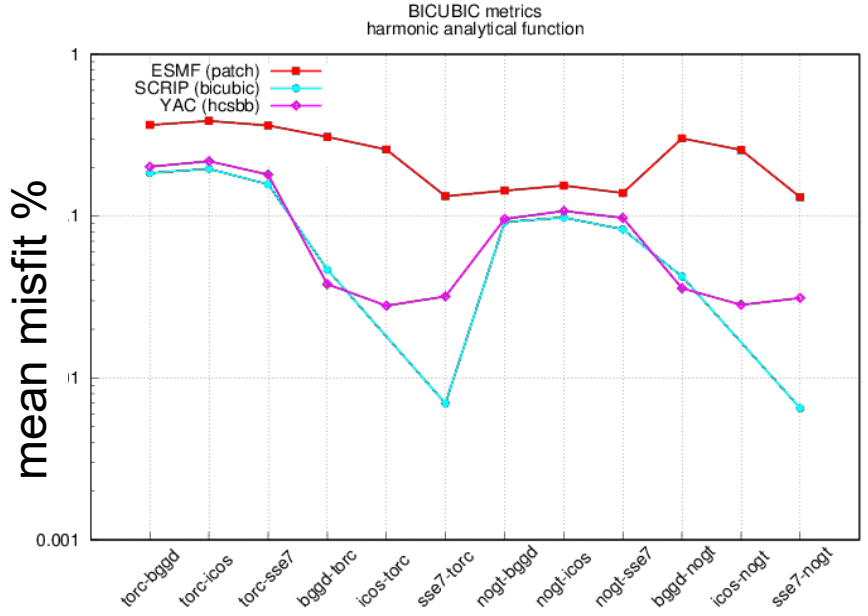
harmonic

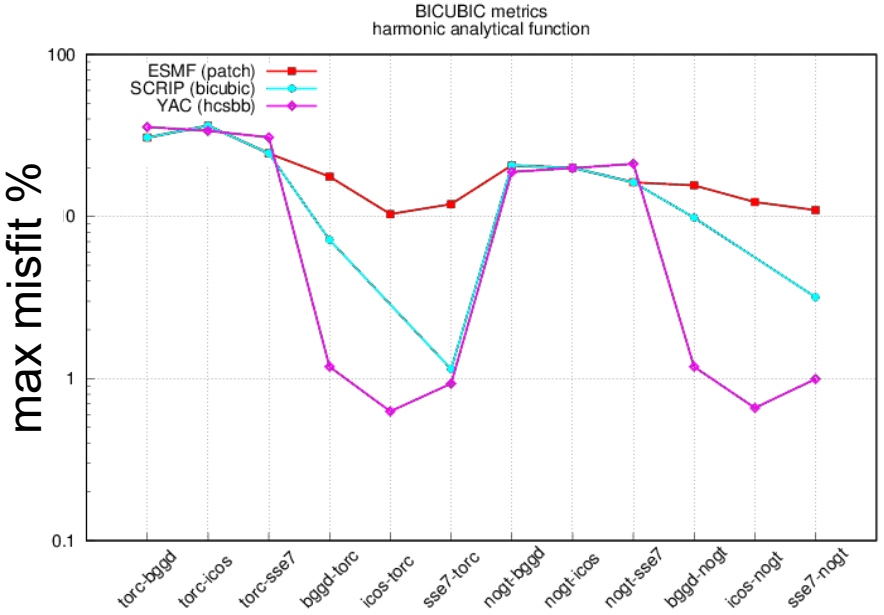
SCRIP (local-coordinate system bicubic approximation, Jones 1999)

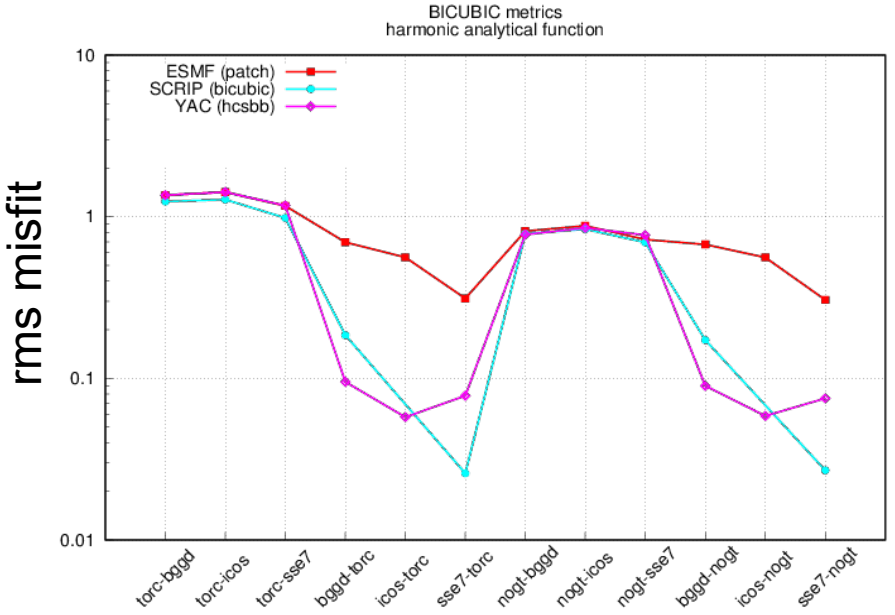
ESMF (multiple 2nd deg 2D polynomial source patches)

YAC (spherical Bernstein-Bézier polynomials, Liu & Schumaker 1996)

not implemented in XIOS nor MTR

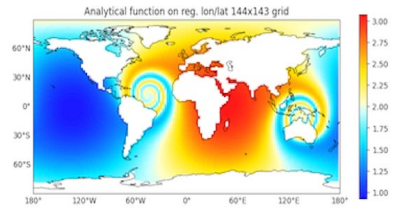






➢ESMF patch less accurate on average

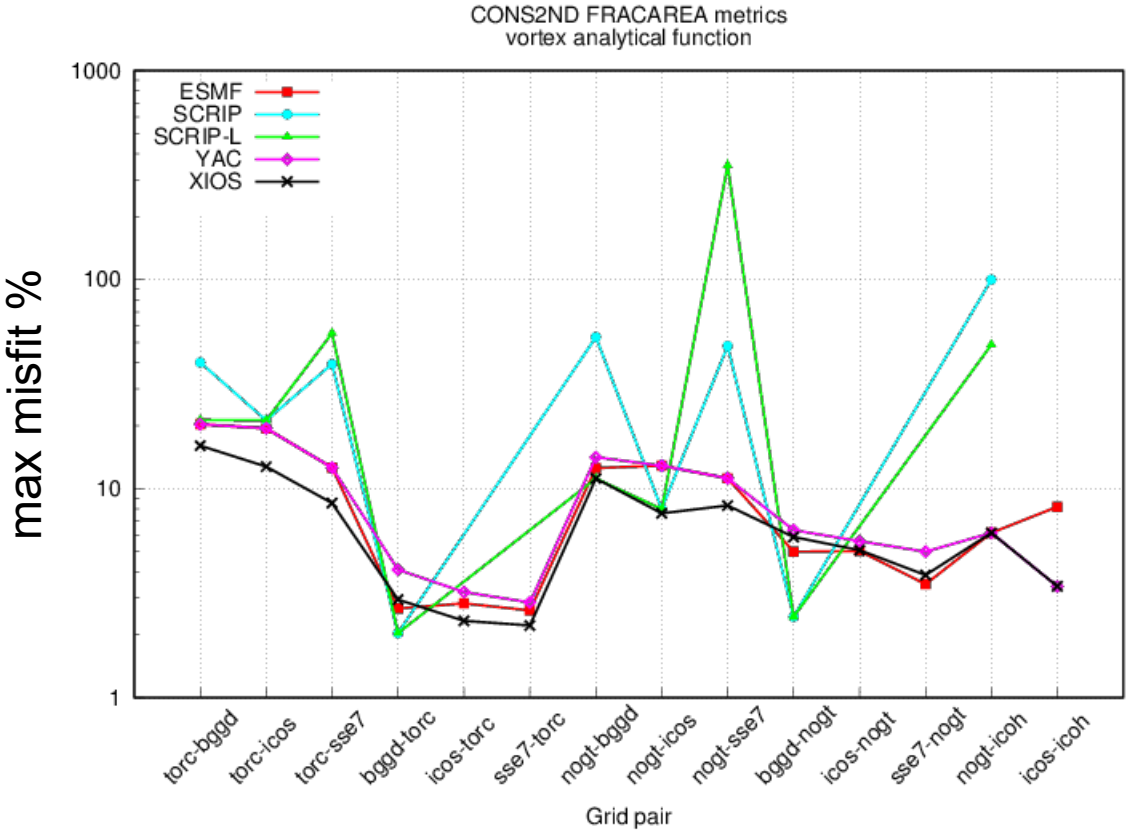
Regridding benchmark –results CONSERV 2nd O

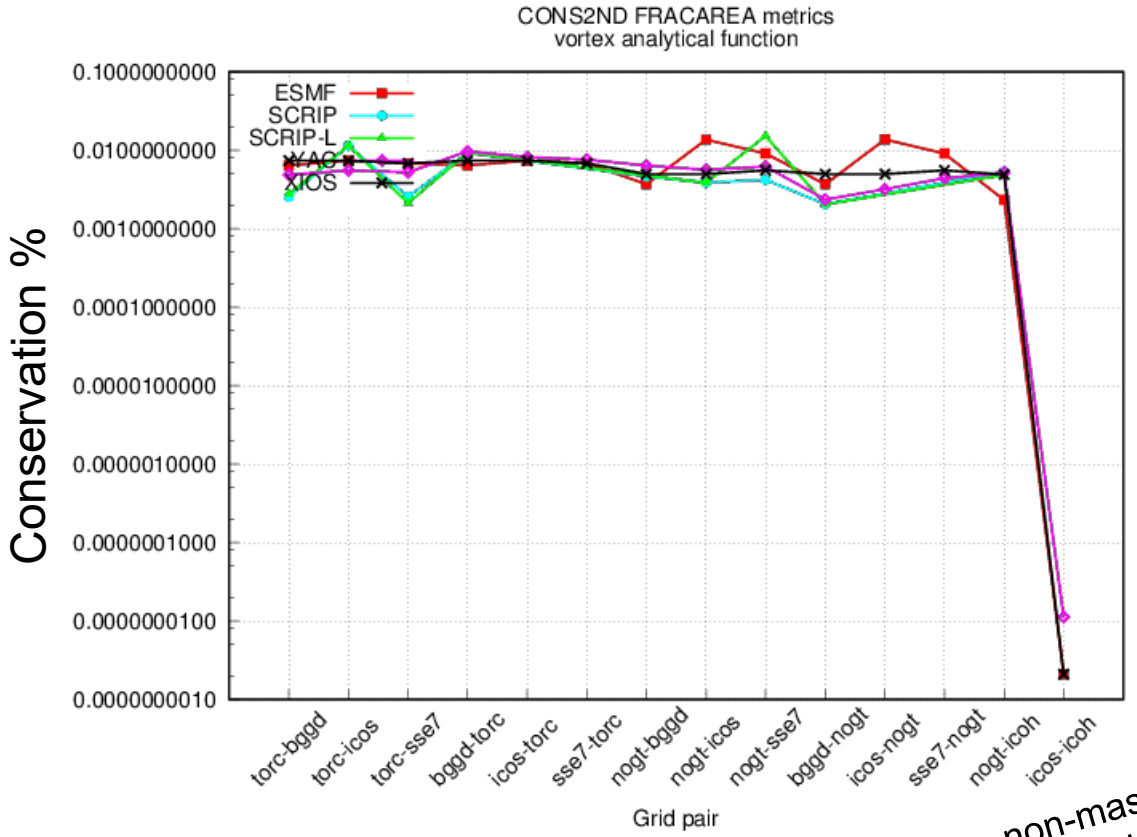


CONSERV 2nd O (FRACAREA)

vortex

SCRIP, SCRIP-L, ESMF, YAC, XIOS



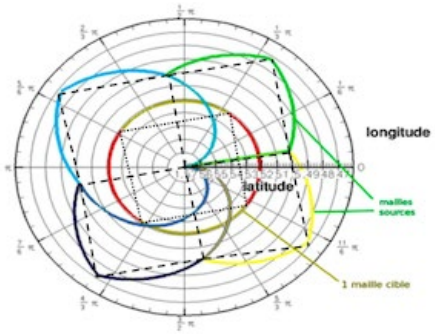


non-masked
icos-icoh

- Good and similar results for XIOS, ESMF and YAC (Kritsikis et al 2017)
- Problems for SCRIP & SCRIP-L (in OASIS3-MCT) for nogt-sse7 and nogt-icoh

SCRIP detailed quality analysis (2019)

SCRIP assumes borders are linear in (lat,lon) and uses Lambert equivalent azimuthal projection near the pole for intersection calculation



Cell distortion near the pole without Lambert projection

For longitude-latitude, logically-rectangular, icosahedral grids, SCRIP :

- with FRACAREA normalization OK with and without Lambert projection
- with DESTAREA normalization OK but
  - For logically-rectangular <-> longitude-latitude, only with Lambert projection
  - For icosahedral -> logically-rectangular, only without Lambert projection

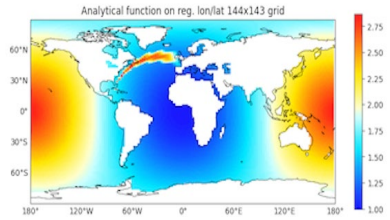
For Gaussian-reduced grids, SCRIP :

- with FRACAREA normalization OK without Lambert projection
- with **DESTAREA normalization not OK: error with & without Lambert projection**

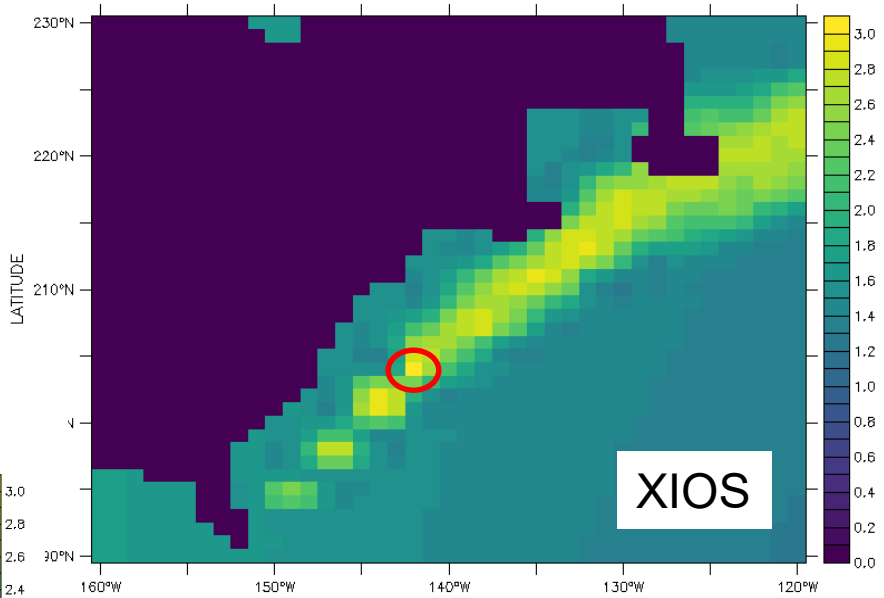
Jonville & Valcke 2019, Valcke & Piacentini 2019 (Cerfacs tech reports)

➢ **need to offer other regridding possibilities in OASIS3-MCT**

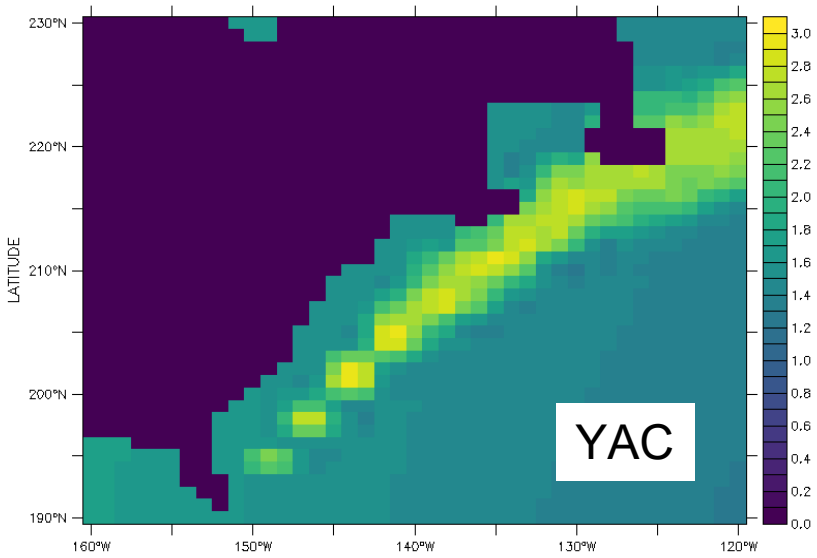
Regridding benchmark –results CONSERV 2nd O



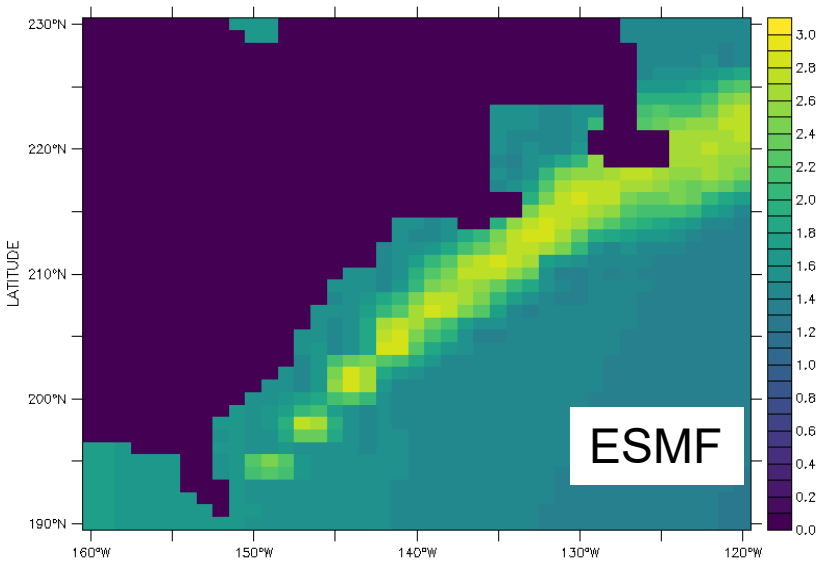
CONSERV 2nd O FRACAREA, gulfstream bggd -> nogt



regridded field



regridded field



regridded field

➢ XIOS overshoots for bggd-nogt (L_{max} XIOS > L_{max} YAC > L_{max} ESMF)

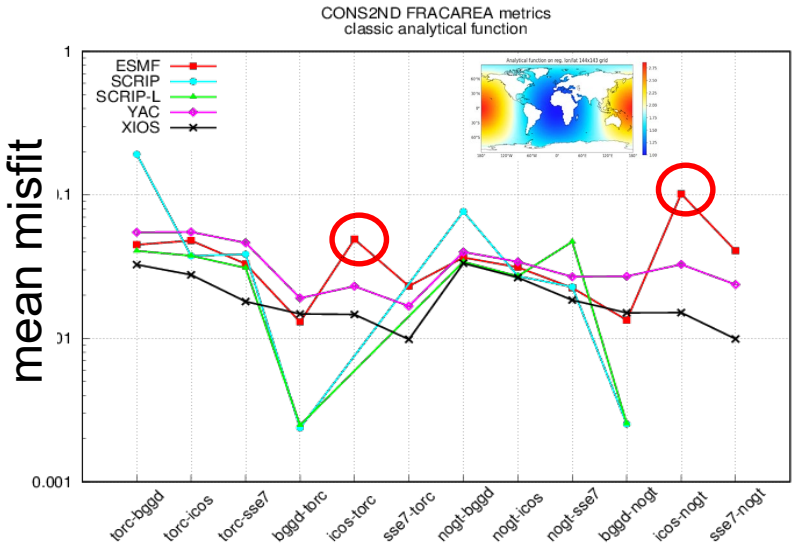
Regridding benchmark – results CONSERV 2nd O

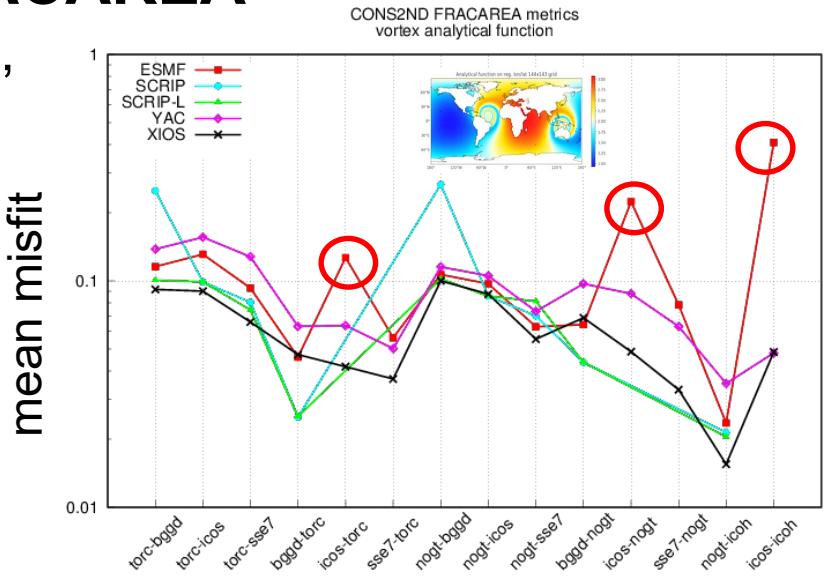
CONSERV 2nd O FRACAREA

sinusoid, harmonic, vortex, gulfstream

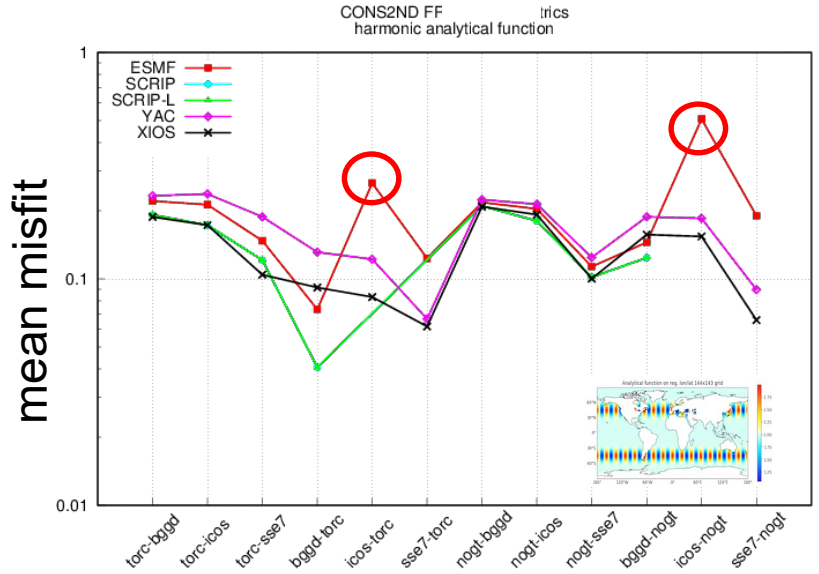
SCRIP, SCRIP-L, ESMF, YAC, XIOS

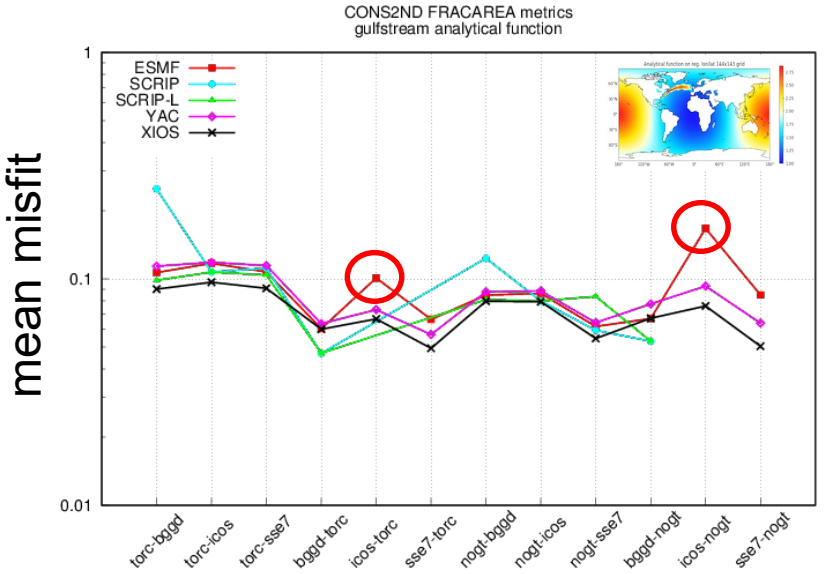
mean misfit





- high mean misfit with ESMF when icosahedral is source.
- working on it with ESMF support!





Regridding benchmark – results CONSERV 2nd O

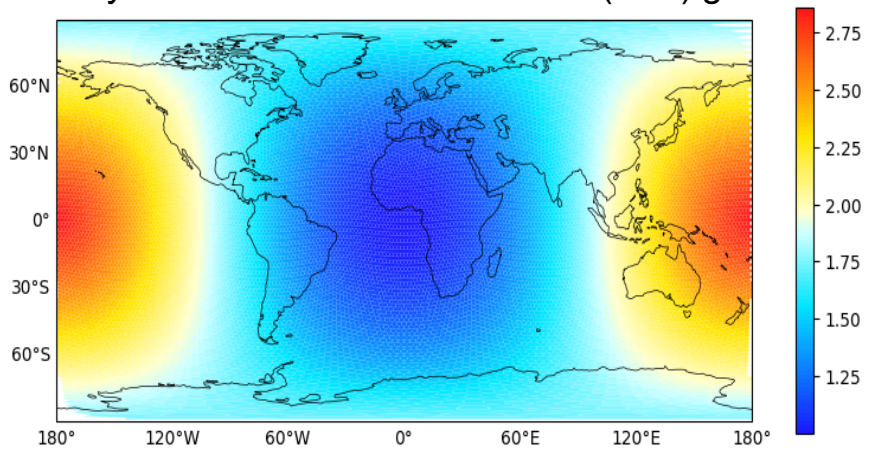
CONSERV 2nd O FRACAREA

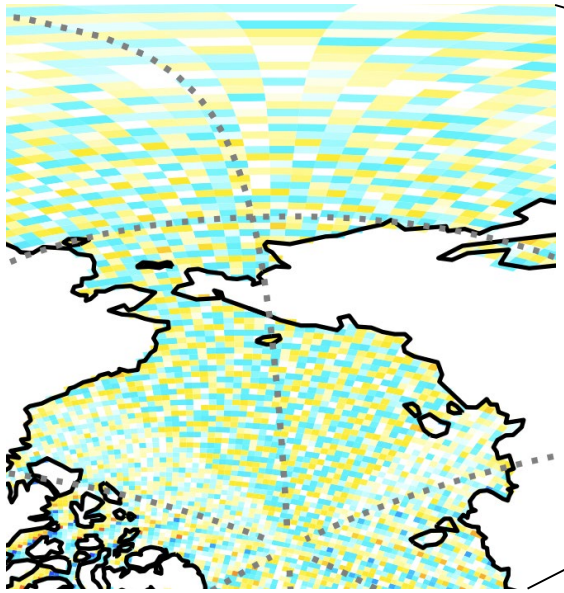
sinusoid

icos->nogt (icosahedral -> NEMO ORCA2)

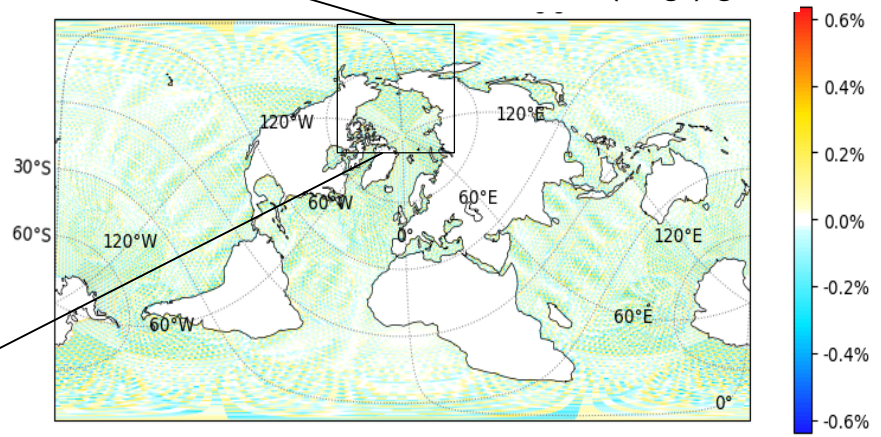
ESMF

Analytical sinusoid on icosahedral (icos) grid





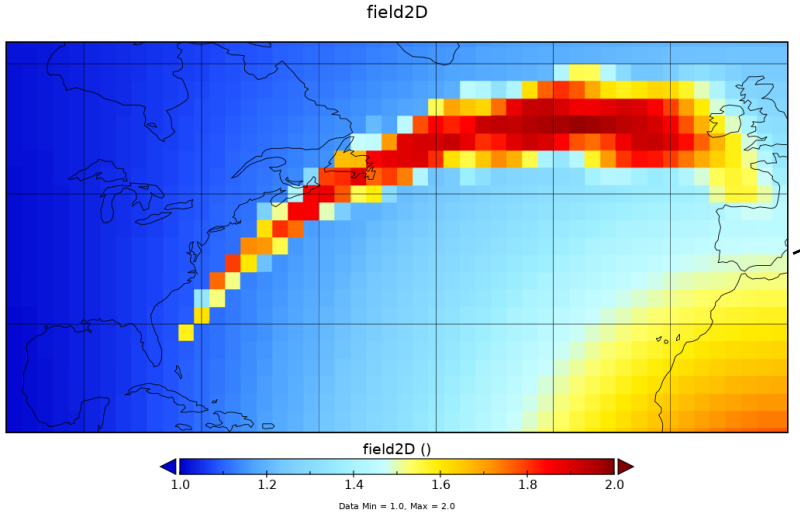
Relative misfit on NEMO ORCA2 (nogt) grid



➢ alternating + and – pattern with ESMF; working on it with ESMF support!

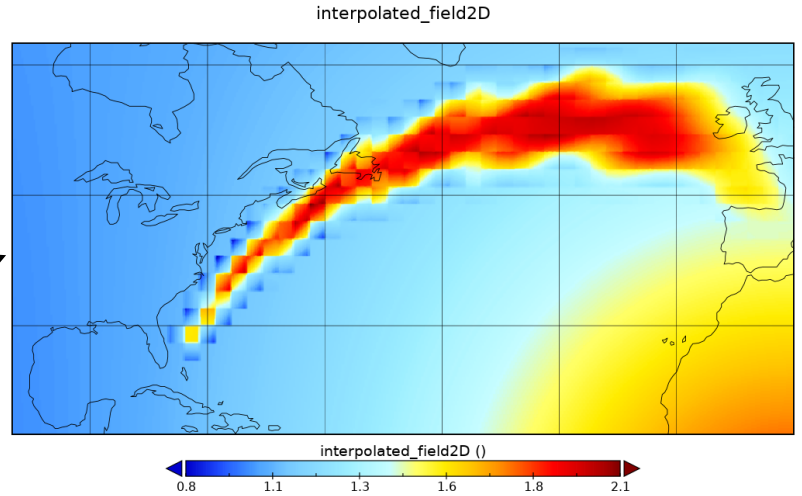
Coupler regridding benchmark

One example of XIOS 2nd O conservative remapping for 2^0 reg lon-lat LMDz to ORCA025

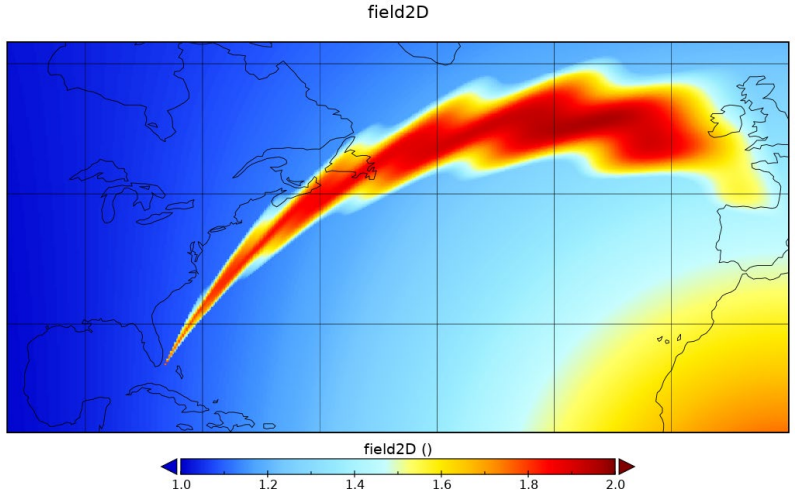


Analytical field on 2^0 reg lon-lat LMDz

2nd order conservative remapping



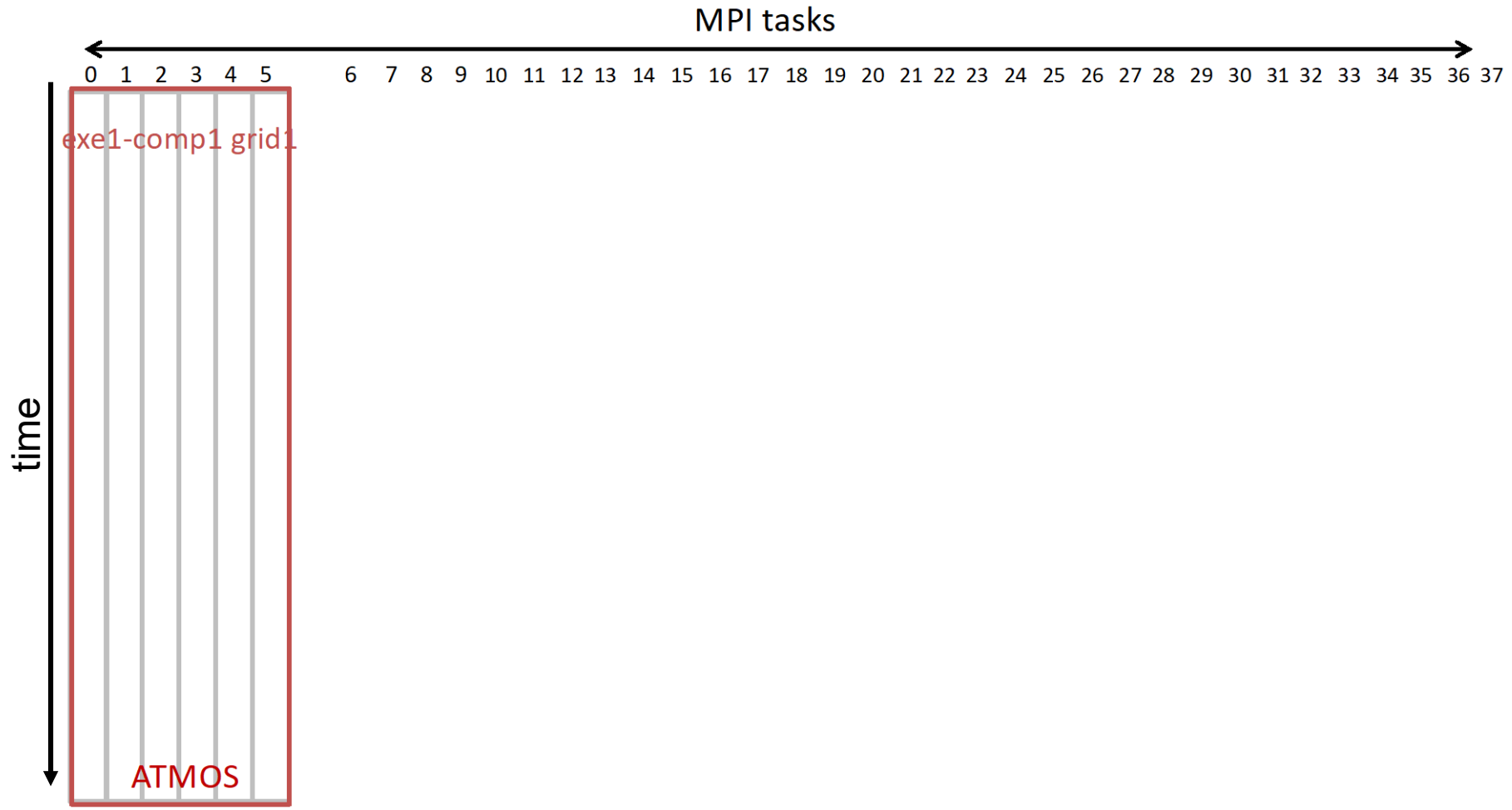
Interpolated field to ORCA025



Analytical field on ORCA025

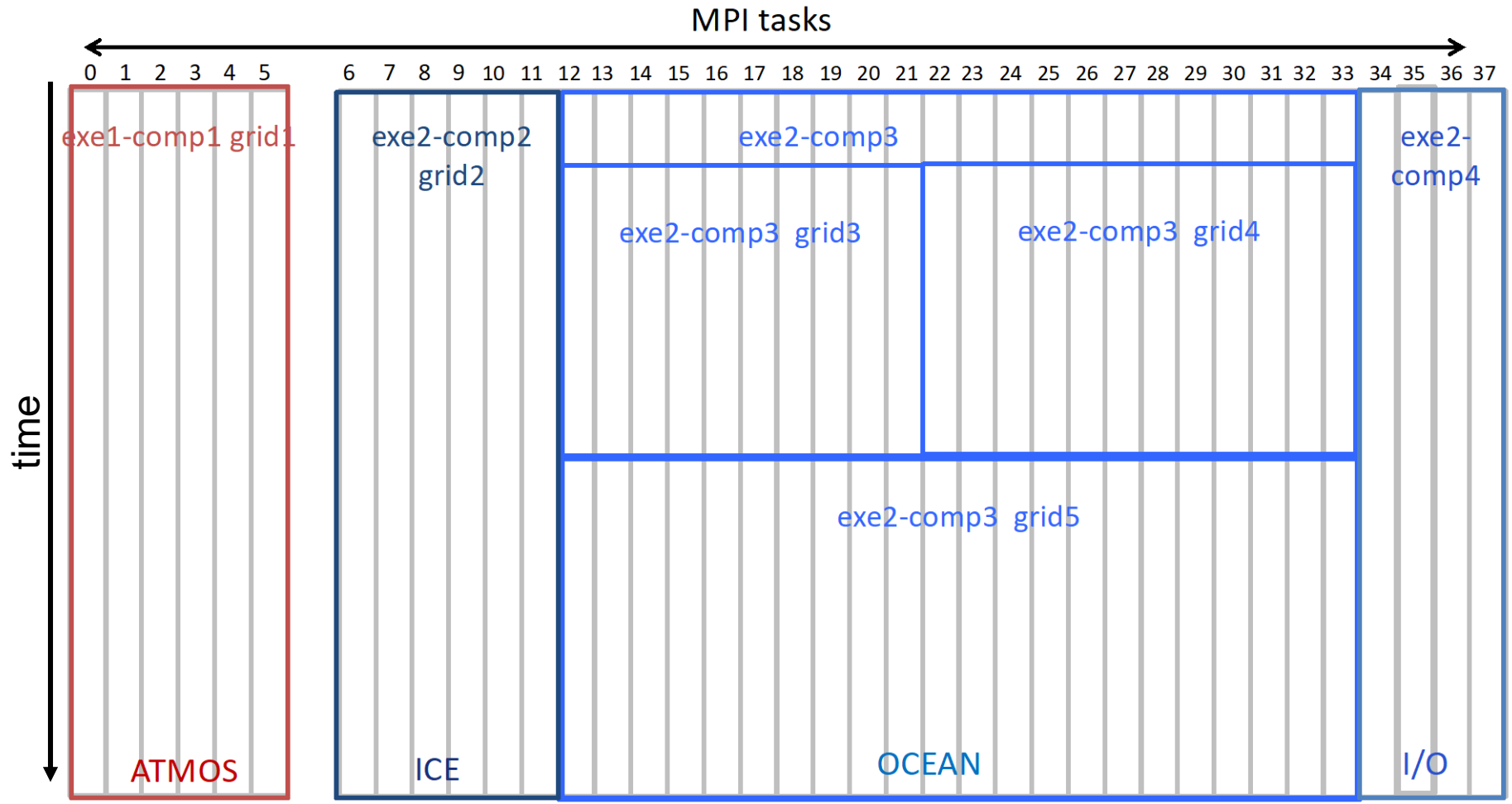
Kritsikis, E., Aechtner, M., Meurdesoif, Y., and Dubos, T.: Conservative interpolation between general spherical meshes, Geosci. Model Dev., 10, 425–431, https://doi.org/10.5194/gmd-10-425-2017, 2017

OASIS3-MCT parallel communication possible topologies of coupling exchanges



Executable 1 has 1 component comp1 that defines grid1

OASIS3-MCT parallel communication
possible topologies of coupling exchanges

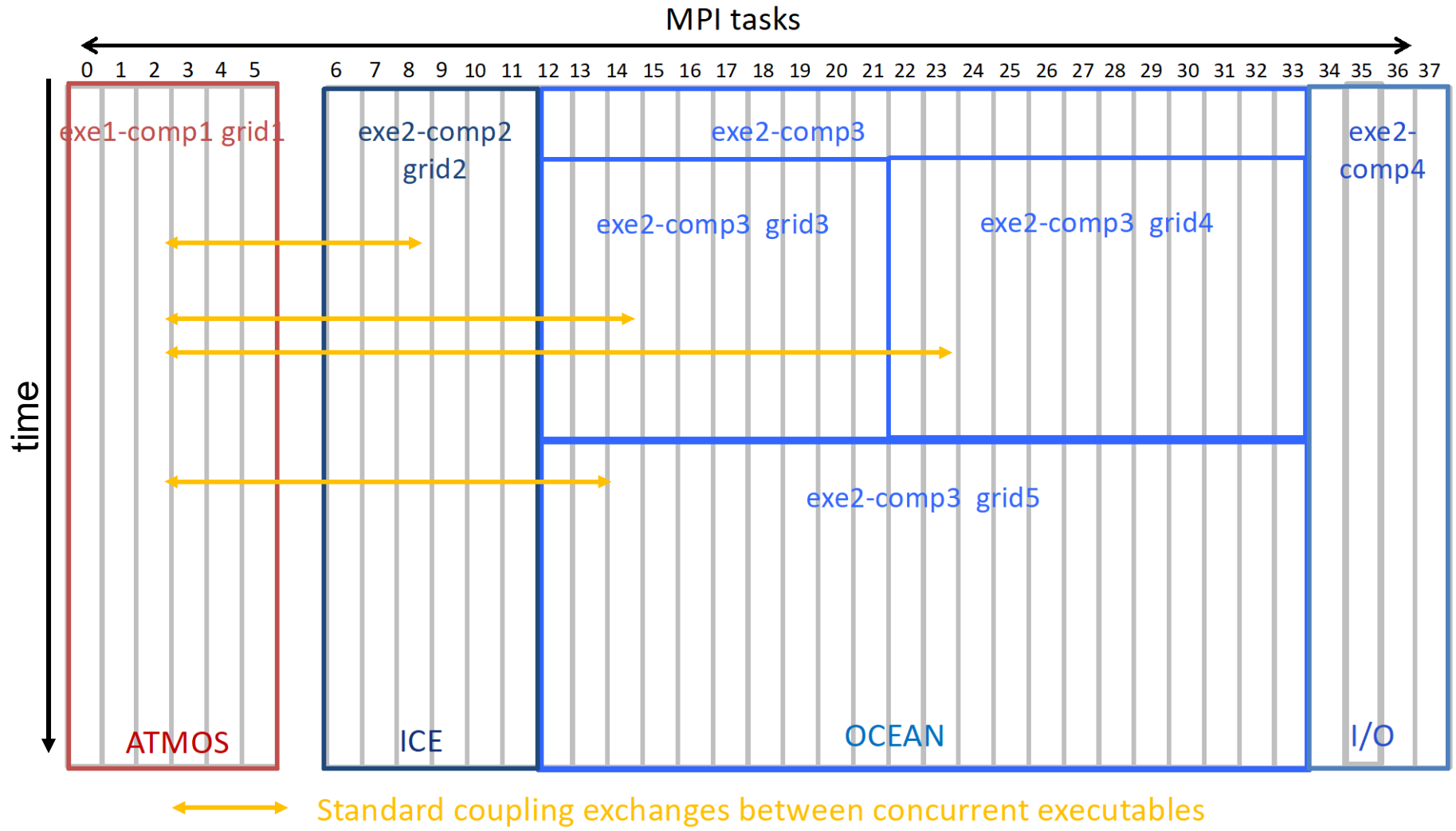


Executable 1 has 1 component comp1 that defines grid1

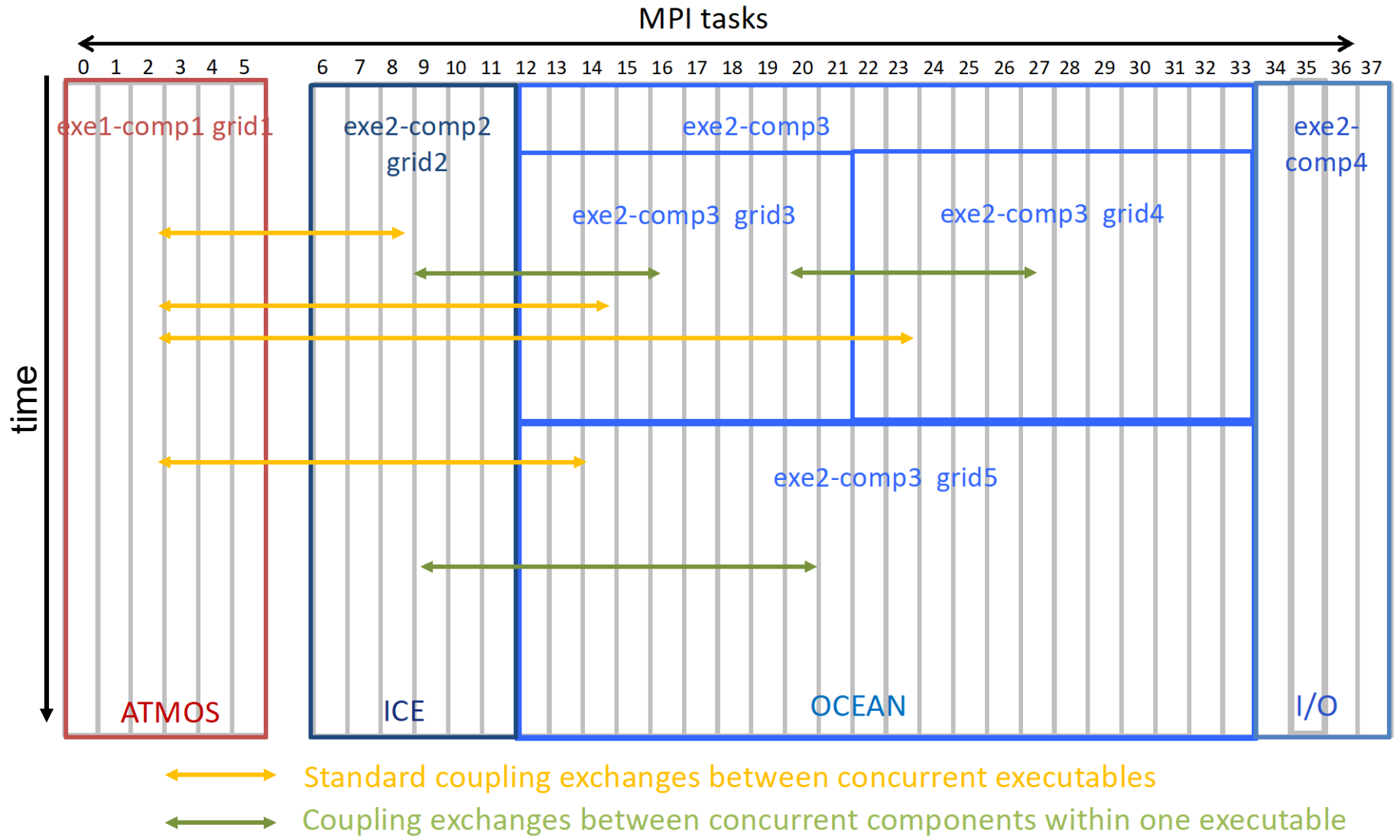
Executable 2 has 3 components;

- comp2 that defines grid2
- comp3 that 3 grids (grid3, grid4, grid5) on subset of processes
- comp4 that is not involved in the coupling

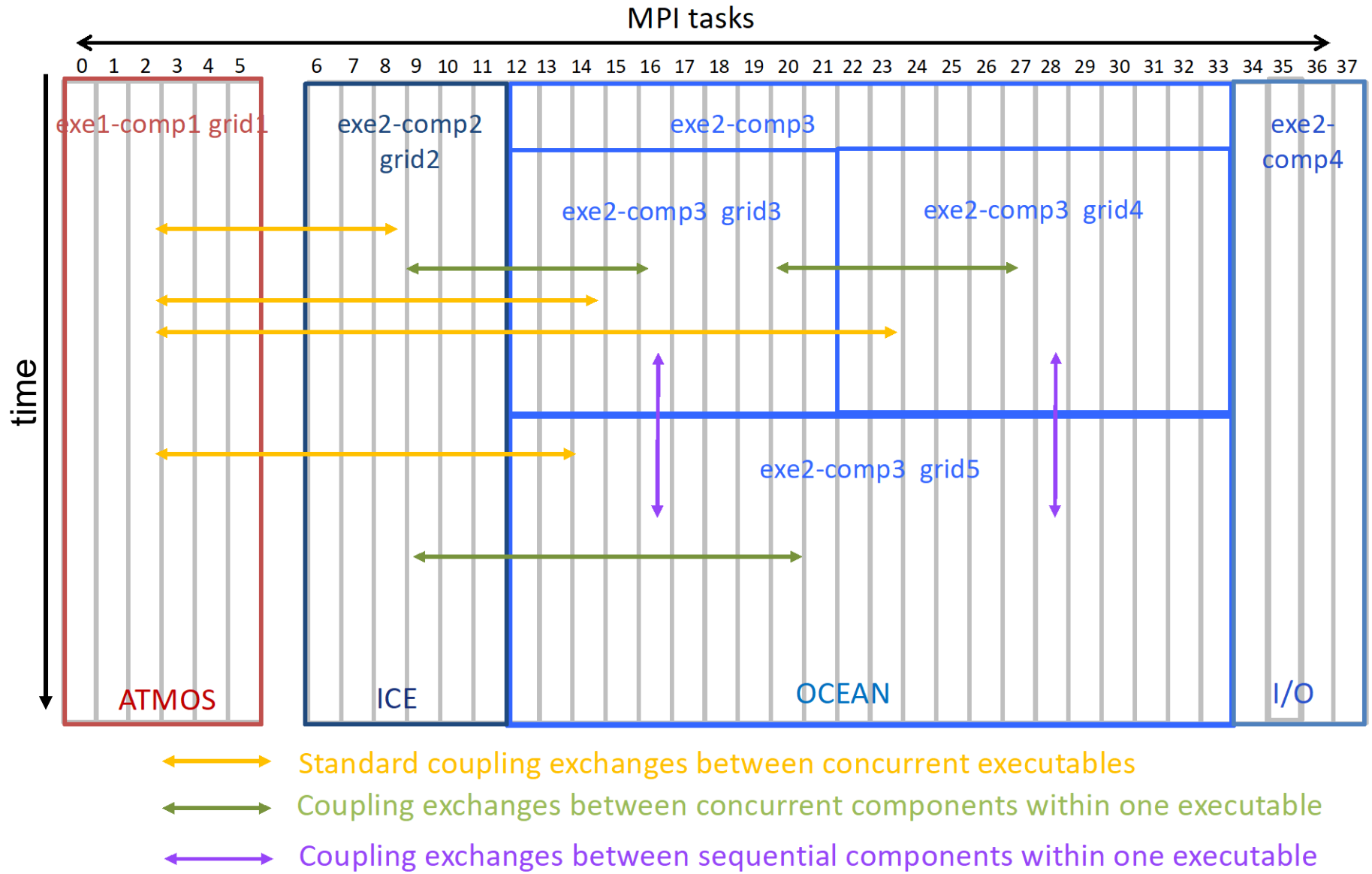
OASIS3-MCT parallel communication possible topologies of coupling exchanges



OASIS3-MCT parallel communication
possible topologies of coupling exchanges



OASIS3-MCT parallel communication possible topologies of coupling exchanges



Extending the functionality, OASIS3-MCT "external coupling library" gets some characteristics of the "integrated coupling framework" approach

Preliminary analysis of regridding libraries

ATLAS (ECMWF)

- no support for masks
- no conservative regridding
  - ➢ useful & portable toolkit for the best usage of heterogeneous architectures but can't be the choice on the short term (Piacentini 2020, CERFACS Tech Rep)

MOAB-TempestRemap (DoE; USA)

- conservative regridding only
- no support of masks (masked cells removed => grid with holes => problems for 2nd O)
  - ➢ not mature enough

YAC (DKRZ; DE)

- dynamic developer (OASIS experience !) but lack of official commitment for support on the long term

ESMF (NASA, NOAA, DoD, NSF; USA)

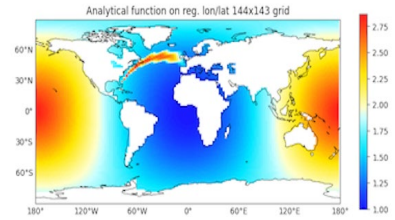
- large community, good long-term perspectives
- good and efficient user support

XIOS (IPSL/CEA, FR):

- conservative regridding only
- growing community, growing number of developers
- natural collaboration with CERFACS

➢ Benchmark YAC, ESMF , XIOS

Regridding benchmark – results 2nd ORDER



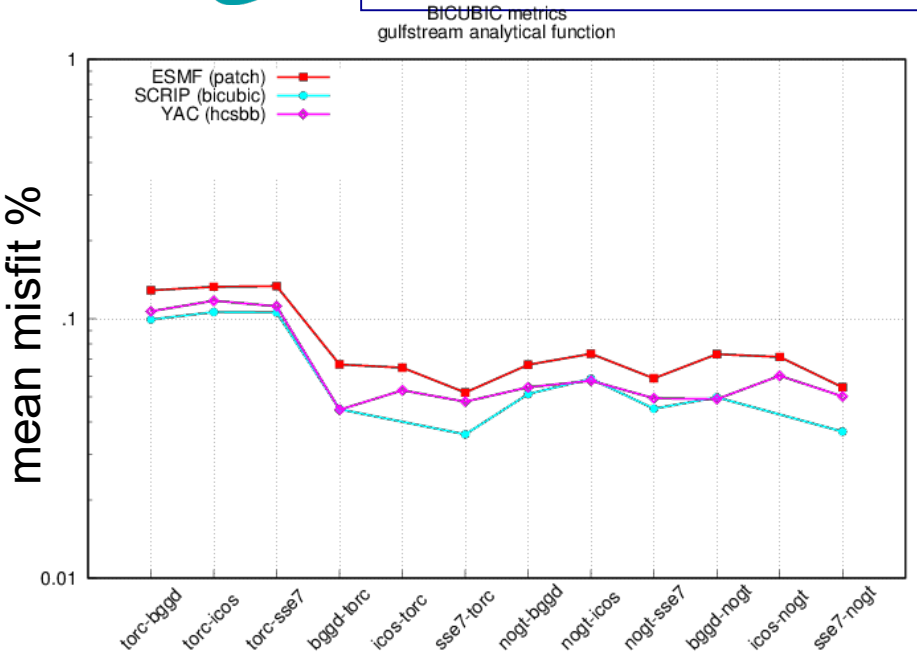
BICUBIC, PATCH, HCSBB

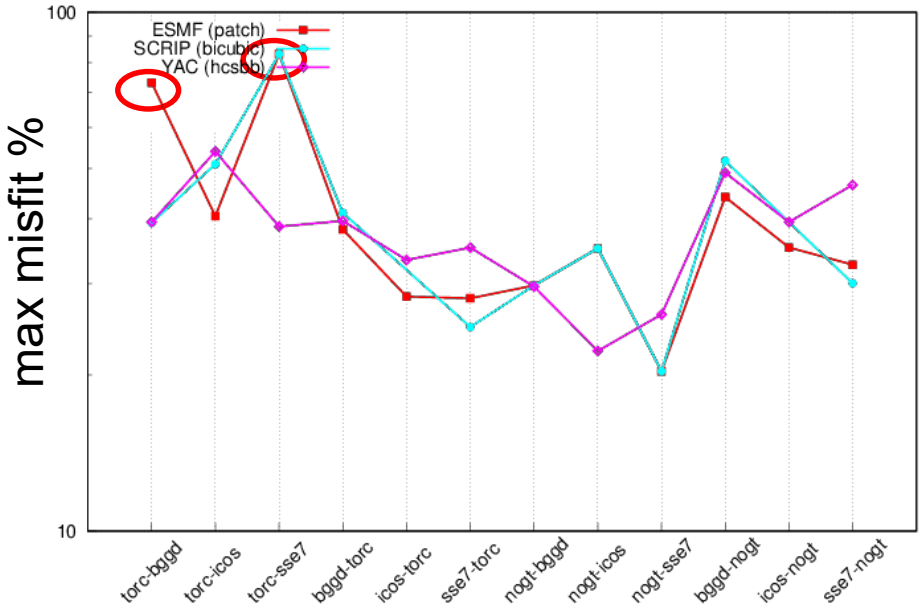
gulfstream

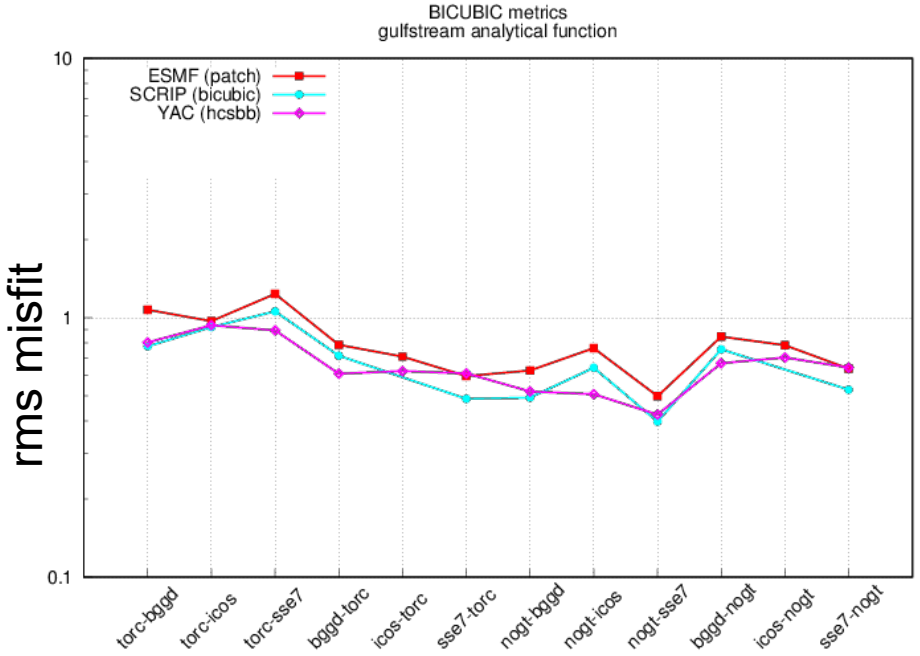
SCRIP (local-coordinate system bicubic approx, Jones 1999)

ESMF (multiple 2nd deg 2D polynomial source patches)

YAC (spherical Bernstein-Bézier polynomials, Hanke & Redler, 2019) (not in XIOS)

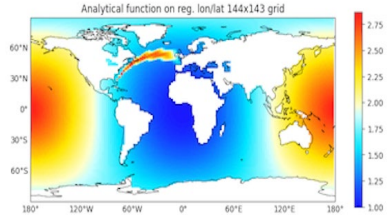






- ESMF patch slightly less accurate on average
- High max misfit for torc-sse7 (ESMF, SCRIP) and **torc-bggd (ESMF)**

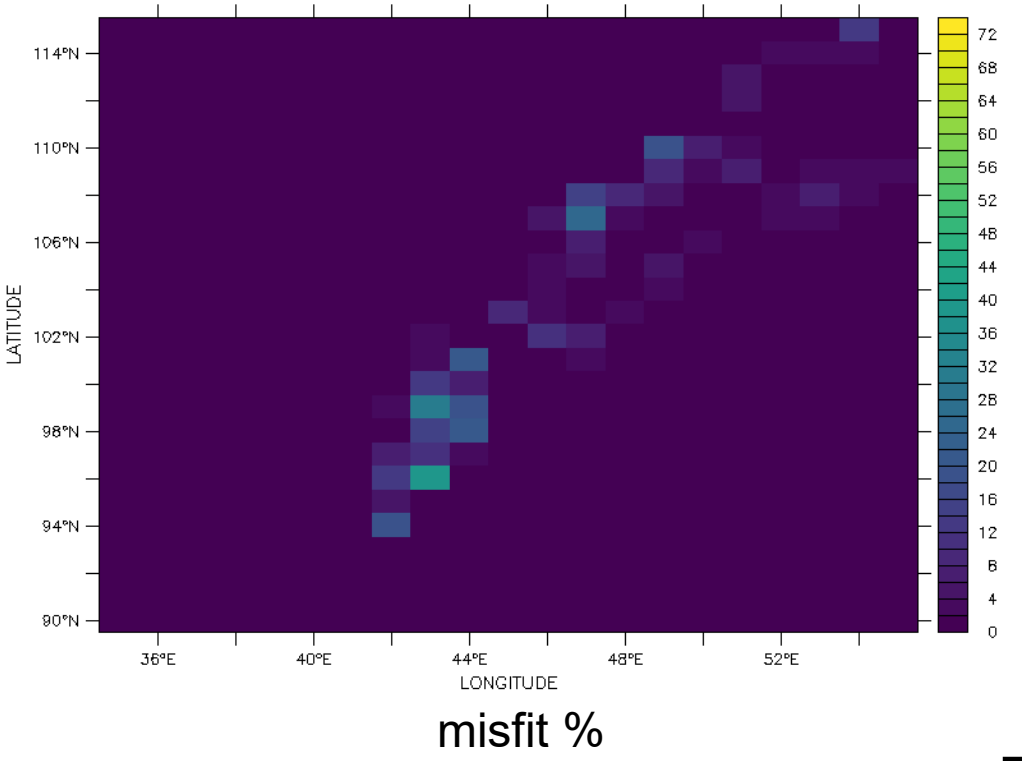
Regridding benchmark – results 2nd ORDER



2nd ORDER, gulfstream, torc -> bggd

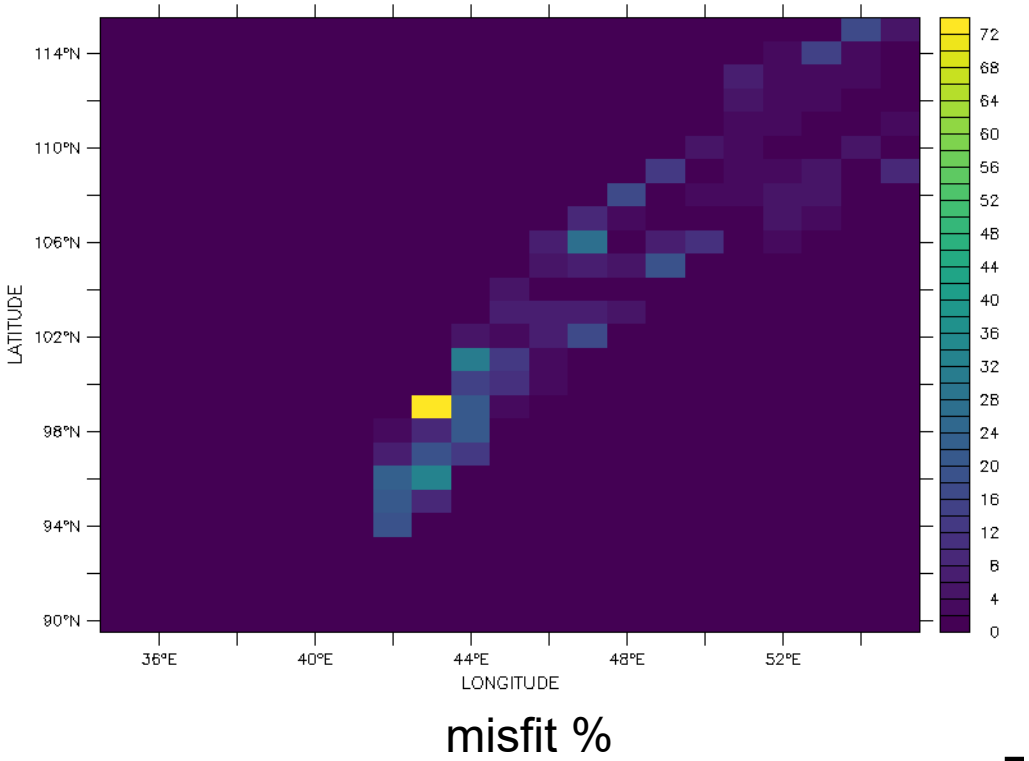
misfit (%) in the gulfstream region

YAC HCSBB



misfit %

ESMF PATCH

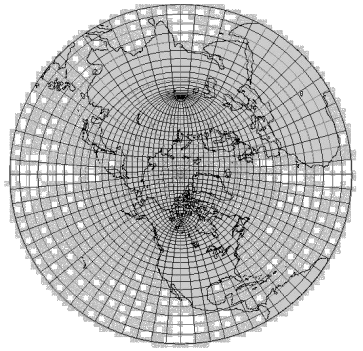


misfit %

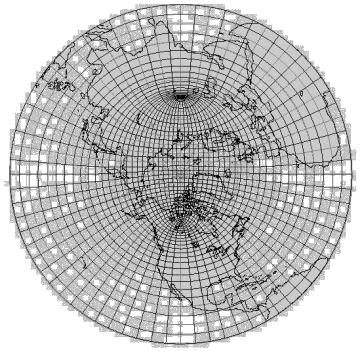
- High ESMF max misfit for torc-bggd for one point near the coast, linked to strong gradient (not visible for harmonic)

Regridding benchmark – results CONSERV 1st O

CONSERV 1st O (DESTAREA) – harmonic – nogt->bggd

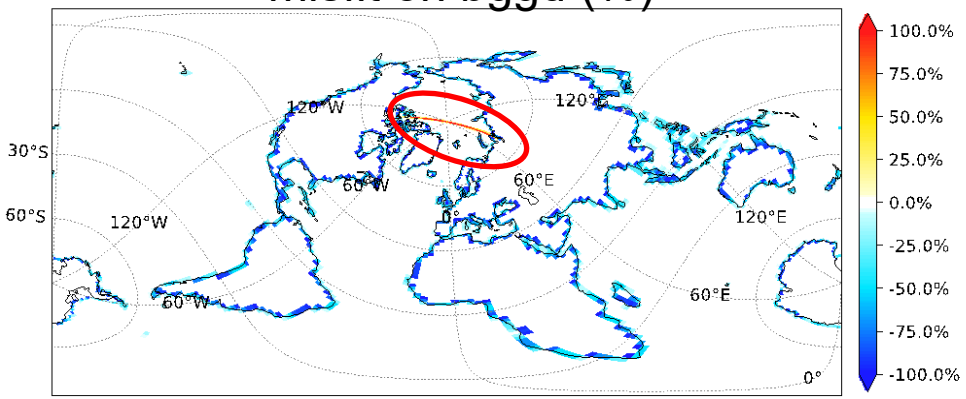


Regridding benchmark – results CONSERV 1st O



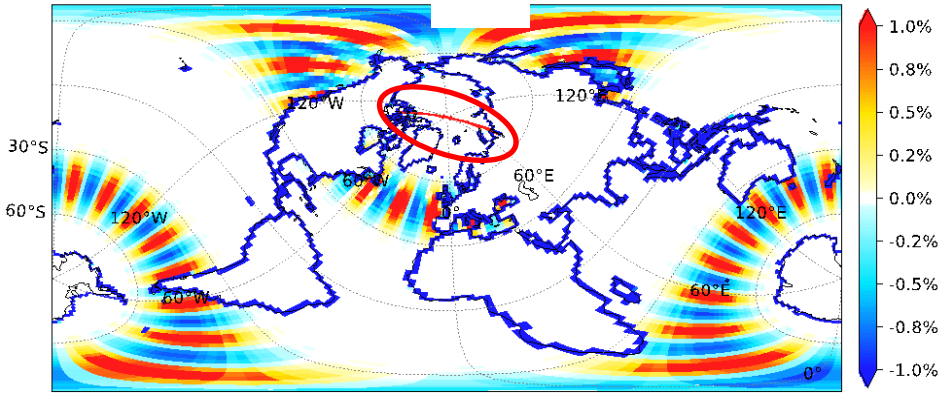
CONSERV 1st O (DESTAREA) – harmonic – nogt->bggd

misfit on bggd (%)

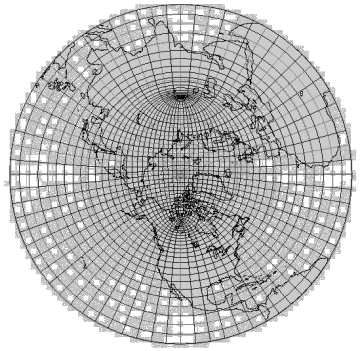


nogt NEMO ORCA1 ***structured***

misfit on bggd (%)

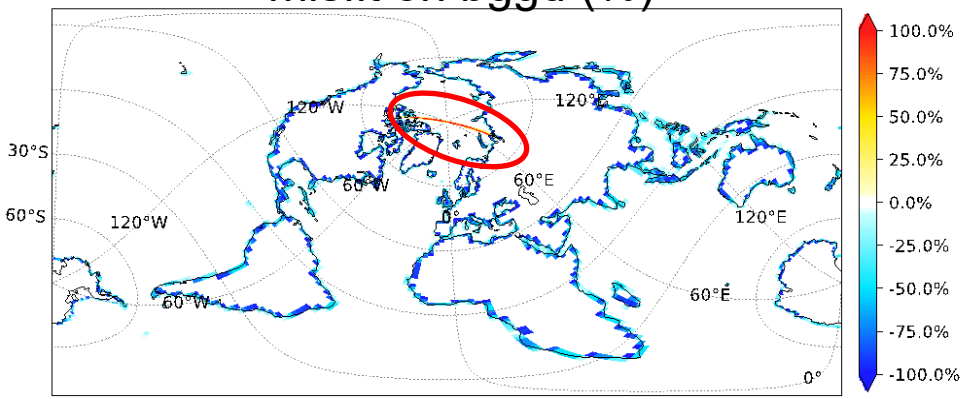


Regridding benchmark – results CONSERV 1st O

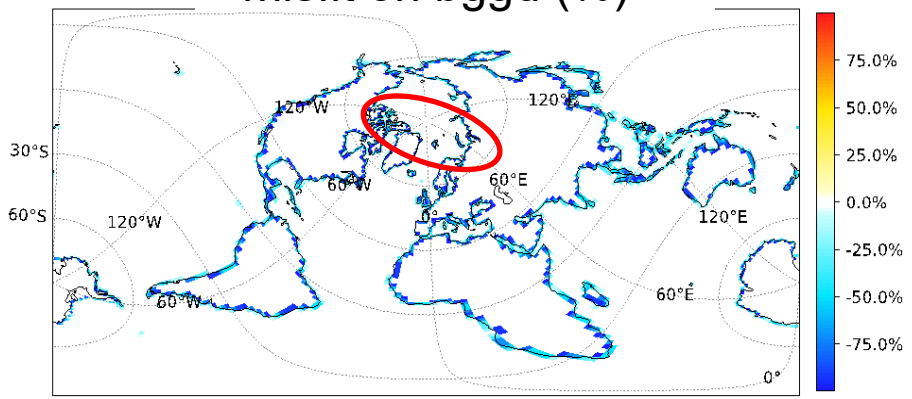


CONSERV 1st O (DESTAREA) – harmonic – nogt->bggd

misfit on bggd (%)

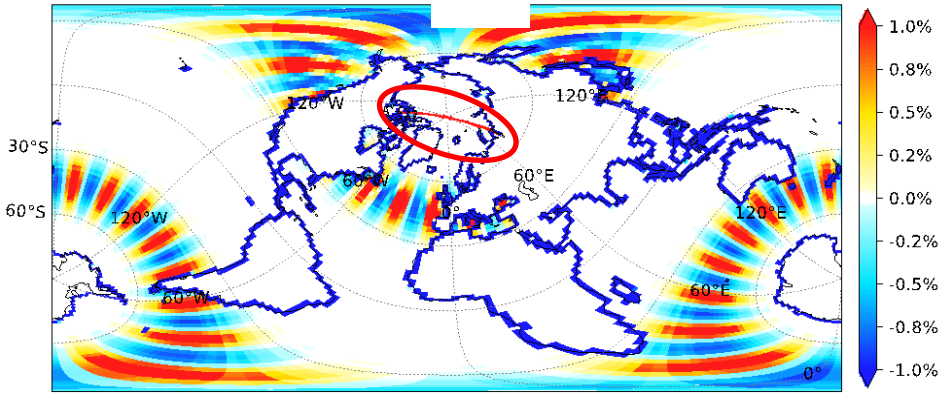


misfit on bggd (%)



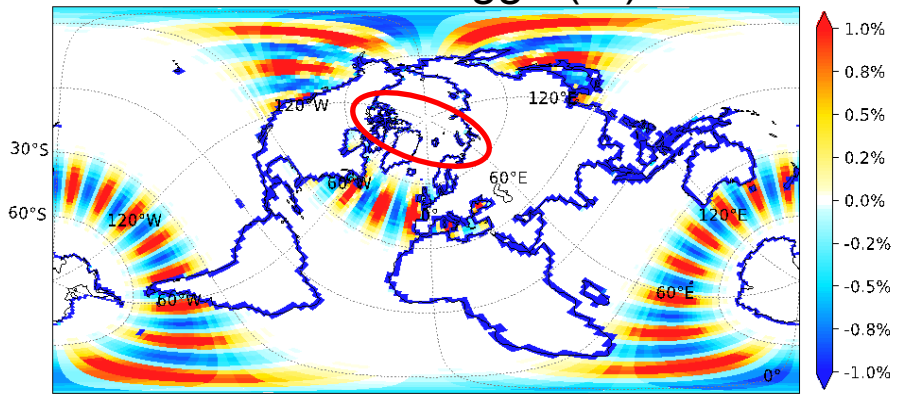
nogt NEMO ORCA1 ***structured***

misfit on bggd (%)



nogt NEMO ORCA1 ***unstructured***

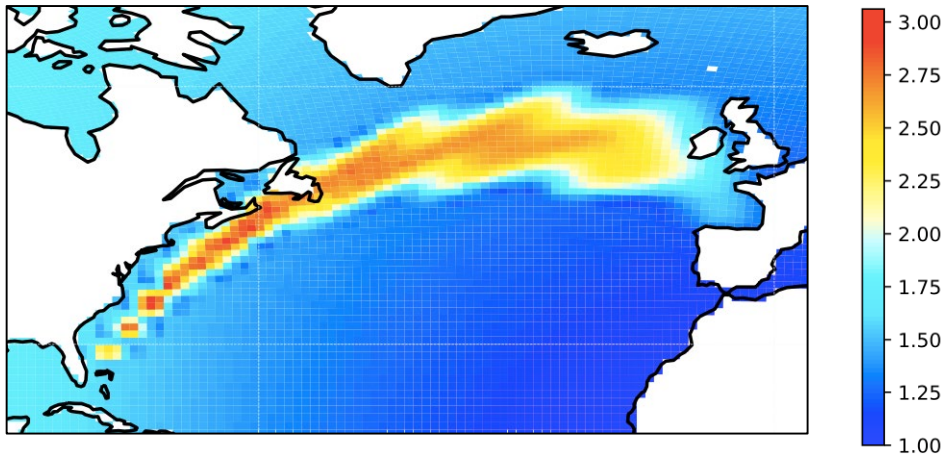
misfit on bggd (%)



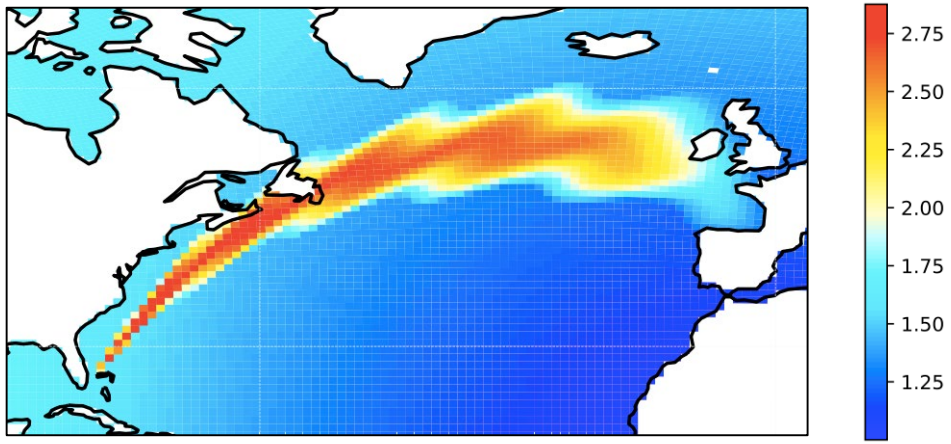
➢ Good results for ORCA grid North fold with ESMF if nogt is declared **unstructured**

Regridding benchmark – results CONSERV 2nd O

regridded function on nogt



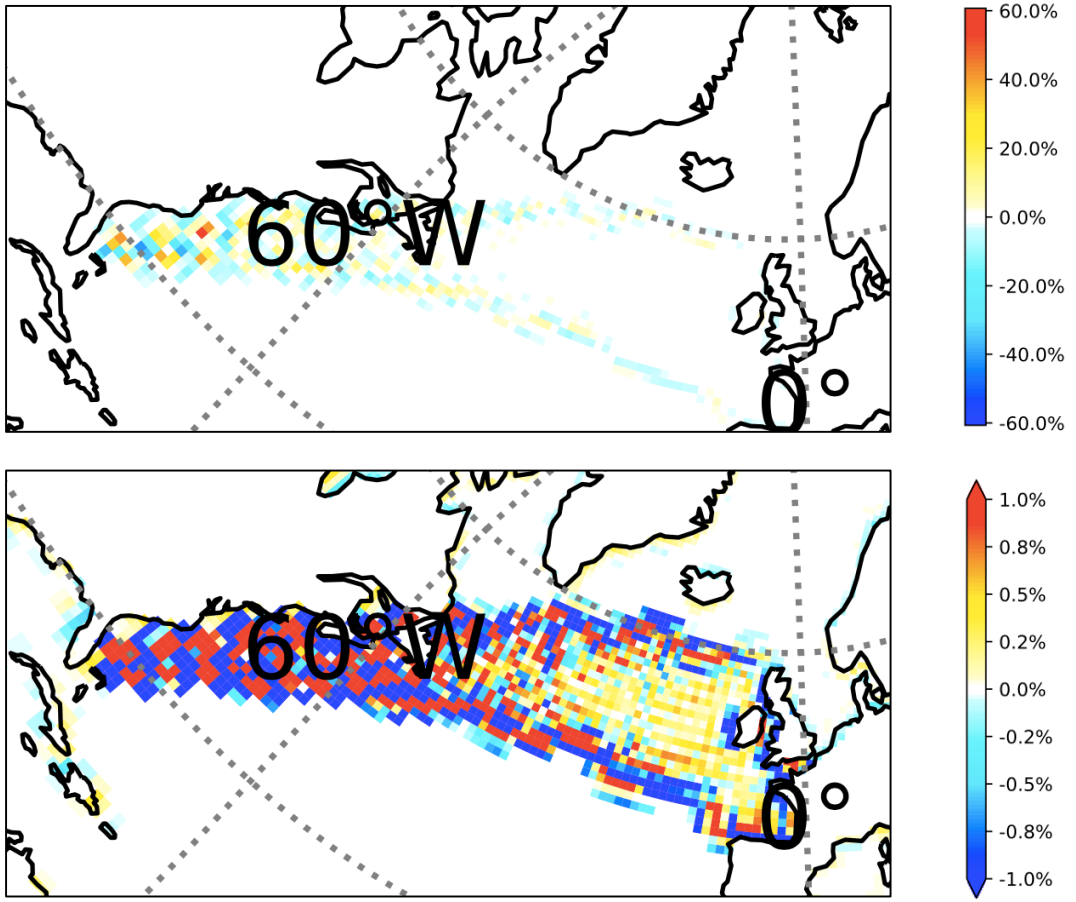
gulfstream function on nogt



CONSERV 2nd O FRACAREA

gulfstream lon-lat (bggd) -> NEMO ORCA1 (nogt)
XIOS, ESMF, YAC

misfit of regridded function on nogt



➢ CONSERV 2nd O shows oscillations near strong gradients (XIOS, ESMF, YAC)