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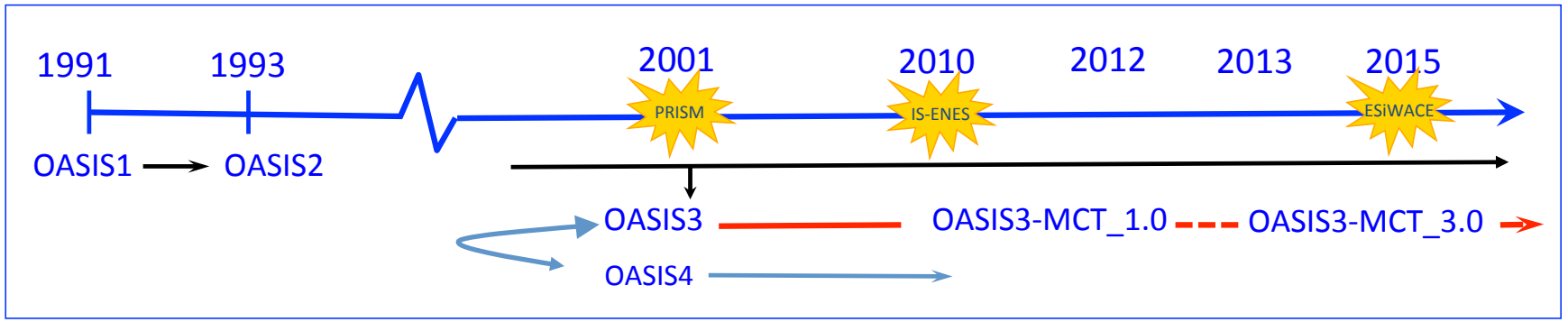
EUROPEAN CENTRE FOR RESEARCH AND ADVANCED TRAINING IN SCIENTIFIC COMPUTING

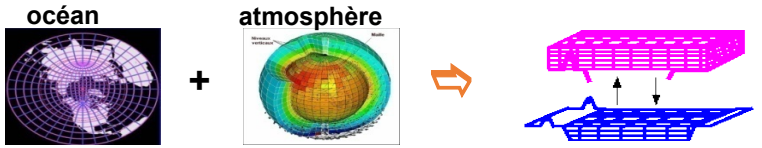
# Latest developments of the OASIS3-MCT coupler for improved performance

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

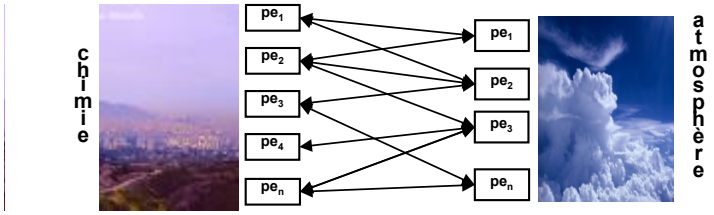
# The OASIS coupler - Introduction




- **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**




➢ F90 & C, LGPL licence LGPL, pubic domain librairies (MPI, NetCDF, SCRIP, MCT)

# The OASIS coupler – Introduction

More than 40 groups in France, Europe and all over the worls use OASIS for climate modelling and seasonnal prediction, e.g.:

- France: CERFACS,CNRM, LOCEAN, LMD, LSCE, LA, LEGOS, LGGE, IFREMER, ENSTA
- Europe: ECMWF + EC-Earth community
- Germany: MPI-M, IFM-GEOMAR, HZG, U. Frankfurt, BTU-Cottbus
- UK: MetOffice, NCAS/U. Reading, ICL,
- Denmark: DMI
- Norway: U. Bergen
- Sweden: SMHI, U. Lund
- Irland: ICHEC, NUI Galway
- Netherlands: KNMI
- Belgium: KU Leuven
- Switzerland: ETH Zurich
- Italy: INGV, ENEA, CASPUR
- Czech Republic : CHMI
- Spain: IC3, BSC, U. Castilla
- Tunisia: Inst. Nat. Met
- Saudi Arabia: CECCR
- Japan: U. Tokyo, JMA, JAMSTEC
- China: IAP-CAS, Met. Nat. Centre, SCSIO
- Corea: KMA
- Australia: CSIRO, BoM, ACT, NCI
- New-Zeland: NIWA, NCWAR
- Canada: Fisheries and Oceans, U. Waterloo, UQAM
- USA: Oregon St. U., Hawaii U., JPL, MIT
- Peru: IGP

+ downloads from du Nigeria, Colombia, Singapour, Russia, Thaïland, …

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

# OASIS3-MCT_4.0 released soon!

## Few additional functionalities:

- Bundle fields
- Automatic writing of coupling restart files
- Check of consistency between the number of weights and fields

## Optimisation and bugfixes

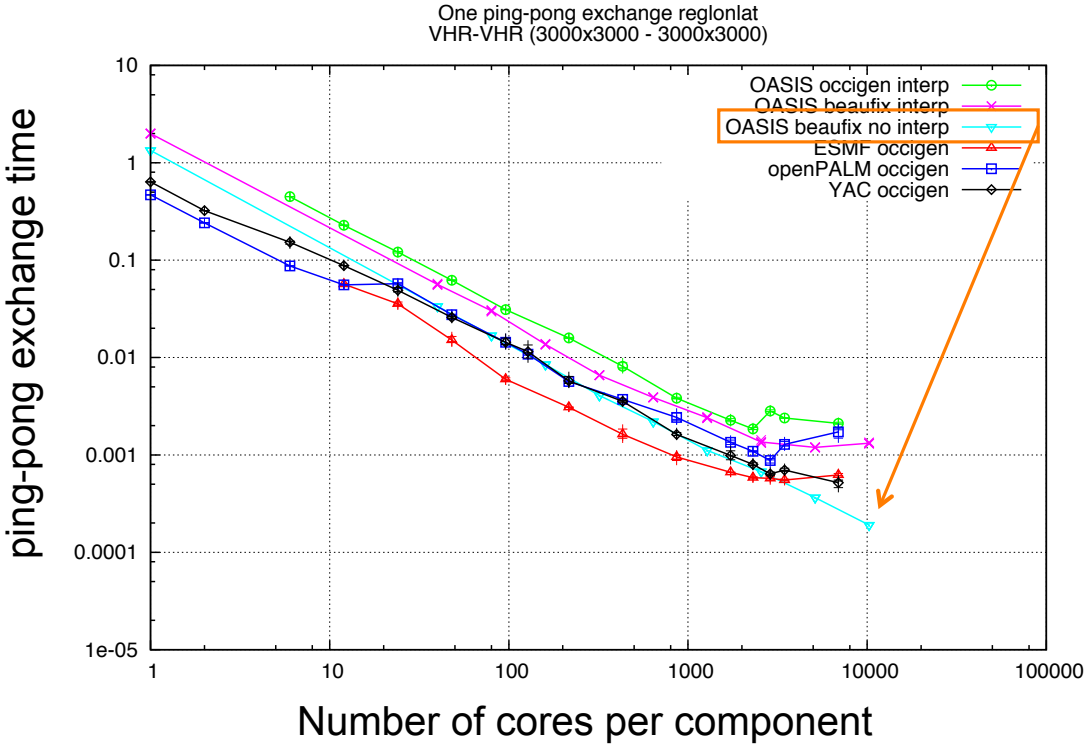
- Activation of « nointerp » for identical grids – impact on IS-ENES2 benchmarks
- New more performant algorithms for the global CONSERV operation
- Upgrade of MCT library
- Debugging of the coupling initialisation
- Optimisation of the communication using the mapping weights
- Hybrid MPI+OpenMP parallelisation of the SCRIP library

**Publications:**

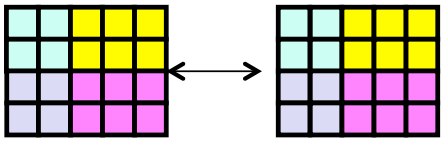

- S. Valcke, L. Coquart, A. Craig, G. Jonville, E. Maisonnave, A. Piacentini, ESiWACE D2.3 “Multithreaded or thread safe OASIS version including performance optimizations to adapt to many-core architectures”
- A. Craig, S. Valcke, L. Coquart, 2017: Development and performance of a new version of the OASIS coupler, OASIS3-MCT_3.0, Geosci. Model Dev., 10, 3297-3308

# Activation of "nointerp" for identical grids – impact on IS-ENES2 benchmark

- "nointerp" : bypass matrix-vector multiplication for identical grids (identity matrix)




IS-ENES2 benchmark VHR:
ping-pong exchange between
3000x3000 regular lat-lon grids
same decomposition



# New algorithms for the global CONSERV operation

CONSERV: forces the global conservation of the coupling field before and after the remapping

In OASIS3-MCT_3.0:

- *bfb* : entire field gathered and summed on the master process, result broadcasted to all other processes
  - bit-for-bit reproducibility
- *opt*: local sum by each process sent to all other processes, then global sum is performed by all
  - more efficient but no bit-for-bit reproducibility

In OASIS3-MCT_4.0:

- *gather* : as *bfb*
- *lsum8:* as *opt*
- *lsum16 :* as *opt/lsum8* but uses quadruple precision
  - more costly but higher chance of reproducibility than *opt/lsum8*
- *reprosum*: fixed point method based on ordered double integer sums(Mirin &Worley, 2012)
  - expected to produce bit-for-bit results except in extremely rare cases
- *ddpdd:* parallel double–double algorithm using a single scalar reduction (He &Ding, 2001)

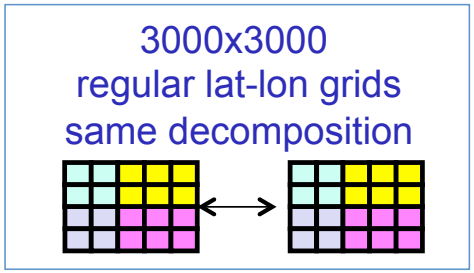
| cores, mapping | CONSERV unset | CONSERV *lsum8* | CONSERV *lsum16* | CONSERV *ddpdd* | CONSERV *reprosum* | CONSERV *gather* |
|---|---|---|---|---|---|---|
| 48, *src* | 4.00 | 8.27 | 16.78 | 10.65 | 17.34 | 117.72 |
| 48, *dst* | 4.39 | 8.02 | 16.59 | 10.42 | 16.98 | 142.12 |
| 180, *src* | 1.25 | 2.21 | 4.59 | 2.87 | 4.85 | 126.91 |
| 180, *dst* | 1.56 | 2.26 | 4.62 | 2.92 | 4.90 | 130.01 |

ORCA025 - T799
Cerfacs Lenovo

- *lsum8* is the fastest
- *reprosum* probably the best choice for bit-for-bit reproducibility as only slightly more expensive than *lsum16*

## ➢ Update of MCT library from version 2.8 to 2.10.beta1

Reduces by O(10) – O(100) the MCT router initialization cost
e.g. for the IS-ENES2 benchmark VHR test case:

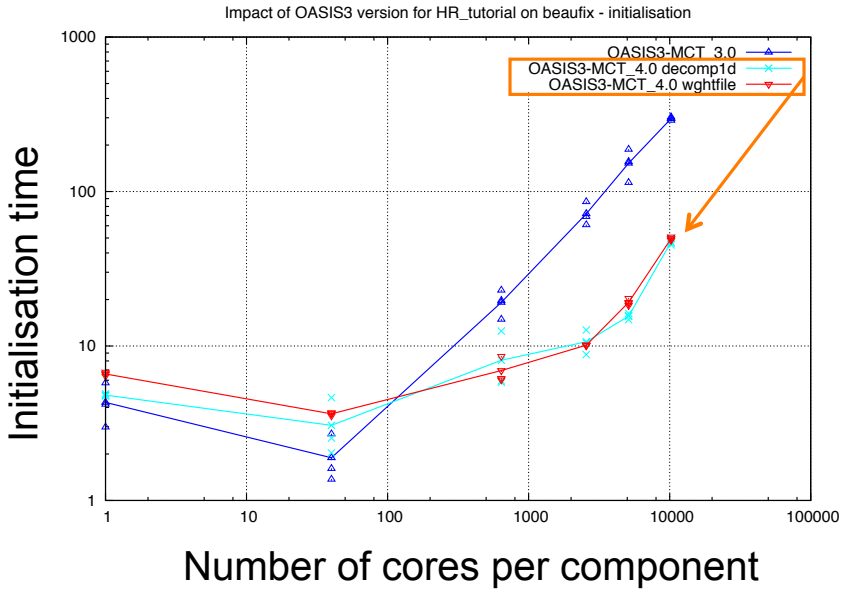



- cost to compute the router between the source and mapping decomposition :
  - 19 sec -> 0.5 sec on 1600 tasks/component
  - 41 sec -> 0.7 sec on 3600 tasks/component
- cost to compute the router between the mapping and target decomposition :
  - 60 sec -> 6-7 sec on 1600 tasks/component
  - 124 sec -> 5-7 sec on 3600 tasks/component

# Debugging of the coupling initialisation

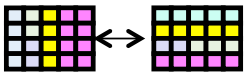
## Bugfix: removal of concurrent writing into the OASIS3-MCT debug files at initialization

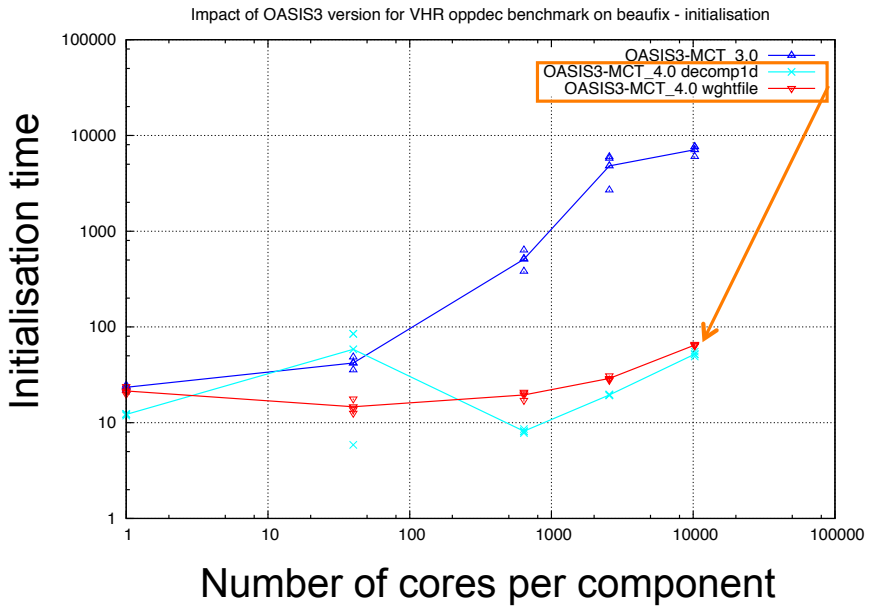
NEMO ORCA025 grid (1021x1442) –
Gaussian Reduced T799 grid (843 000)




⇒ 82% reduction in init time at 10240 cores

IS-ENES benchmark VHR: 3000x3000
reg lat-lon grids, opposite decompositions



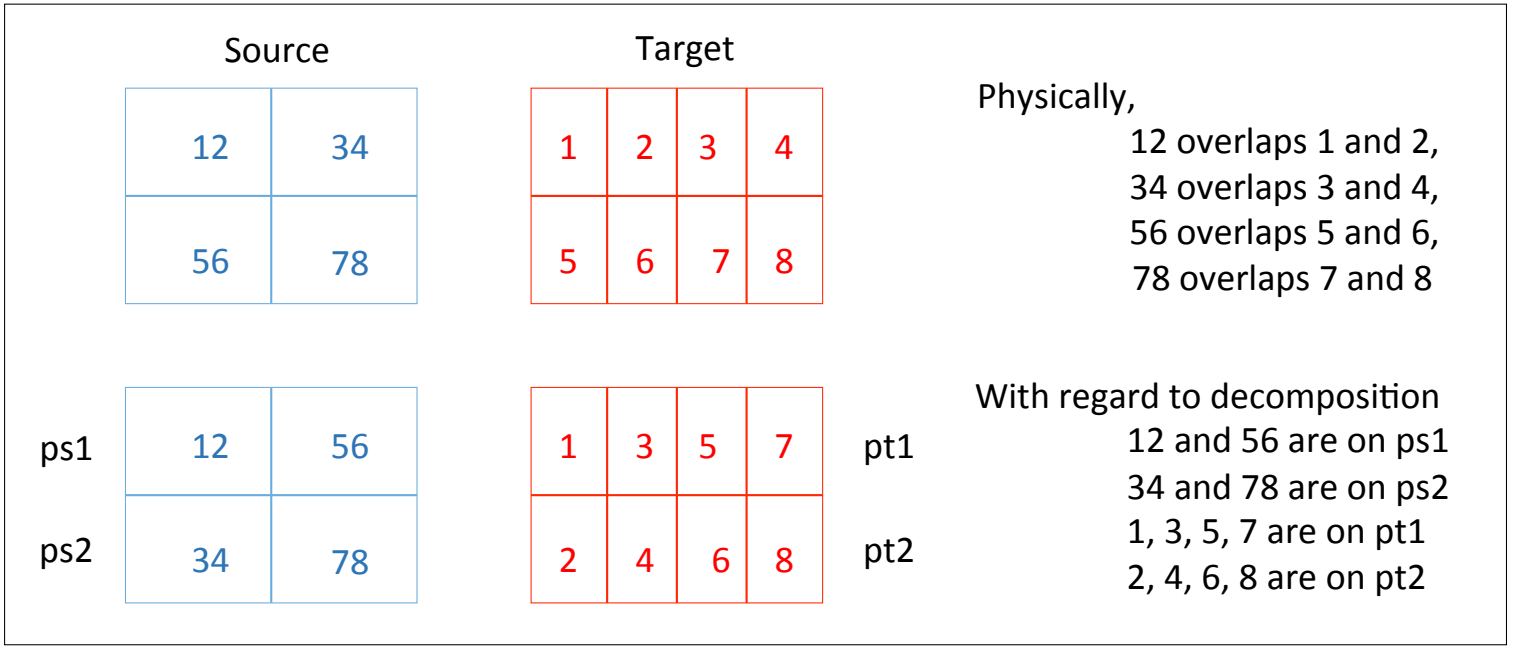



⇒ 99% reduction in init time at 10240 cores

# Optimisation of the communication using the mapping weights

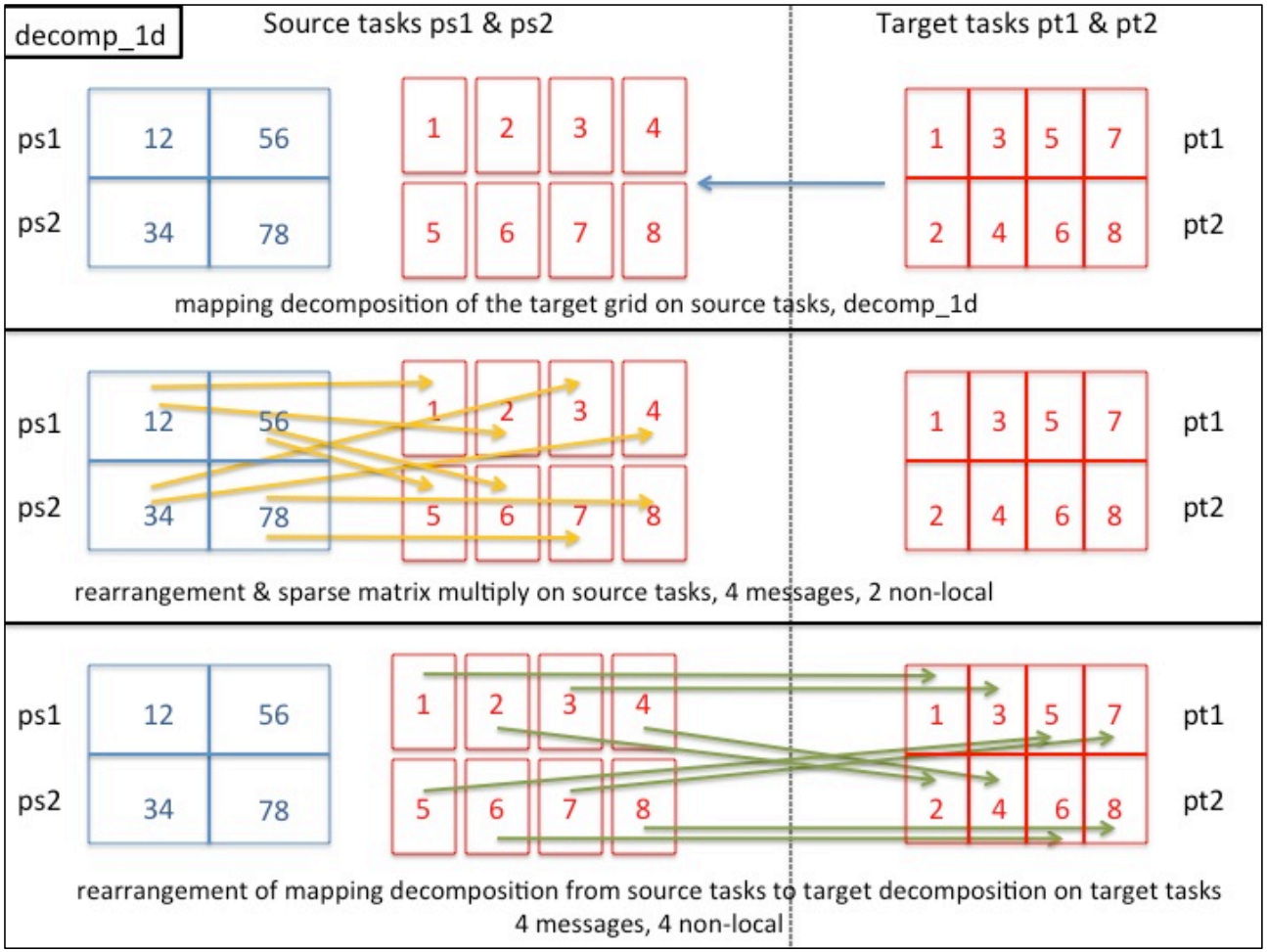
To perform the remapping, a "mapping decomposition" of the target grid on the source tasks is created:

- *decomp_1d :* each target grid point is assigned to a source task in a trivial 1-D way (as in OASIS3-MCT_3.0 )
- *decomp_wghtfile:* a target grid point is associated with the source task which holds the source grid points needed for the calculation of its interpolated value



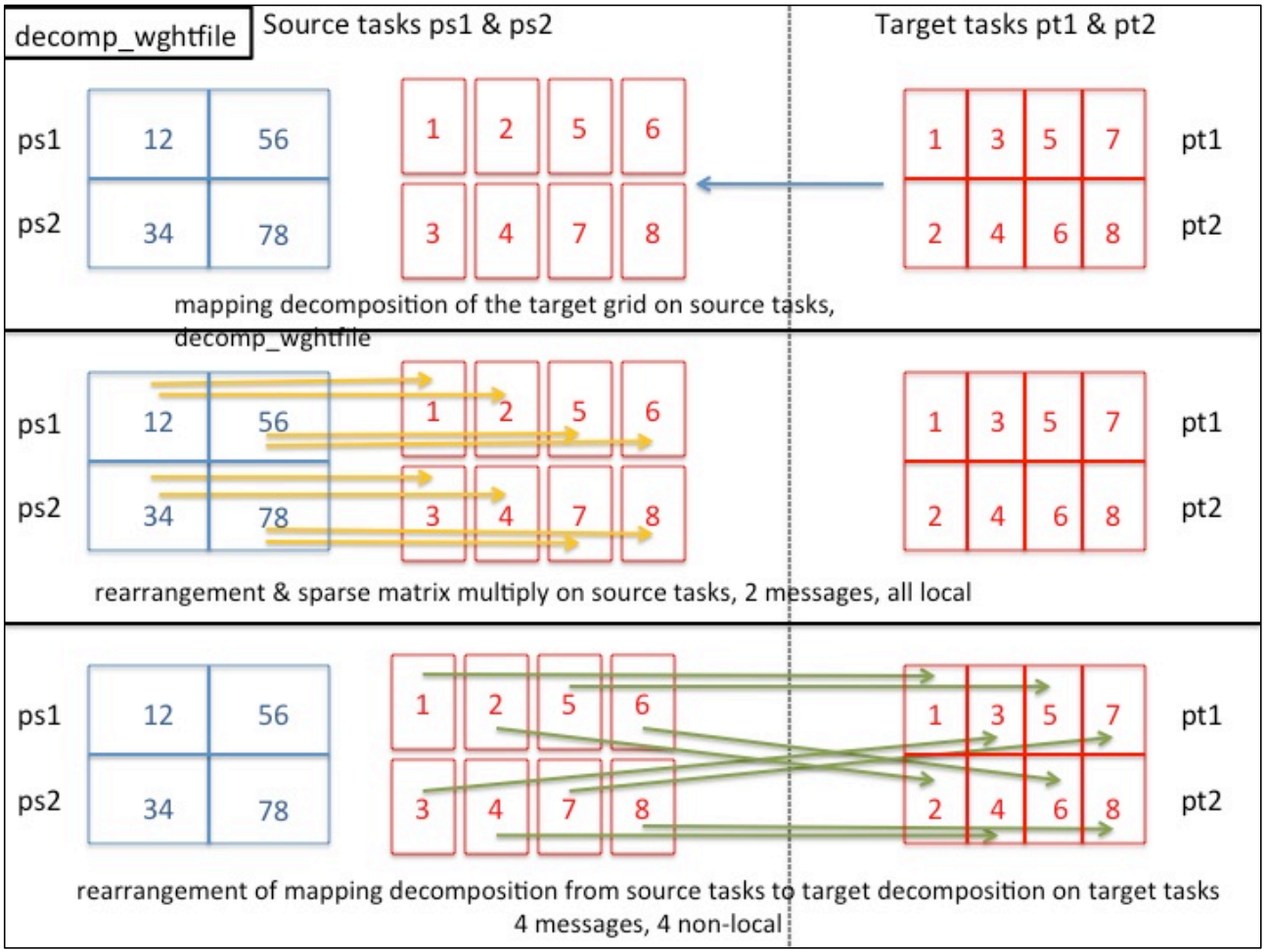
# Optimisation of the communication using the mapping weights

decomp_1d



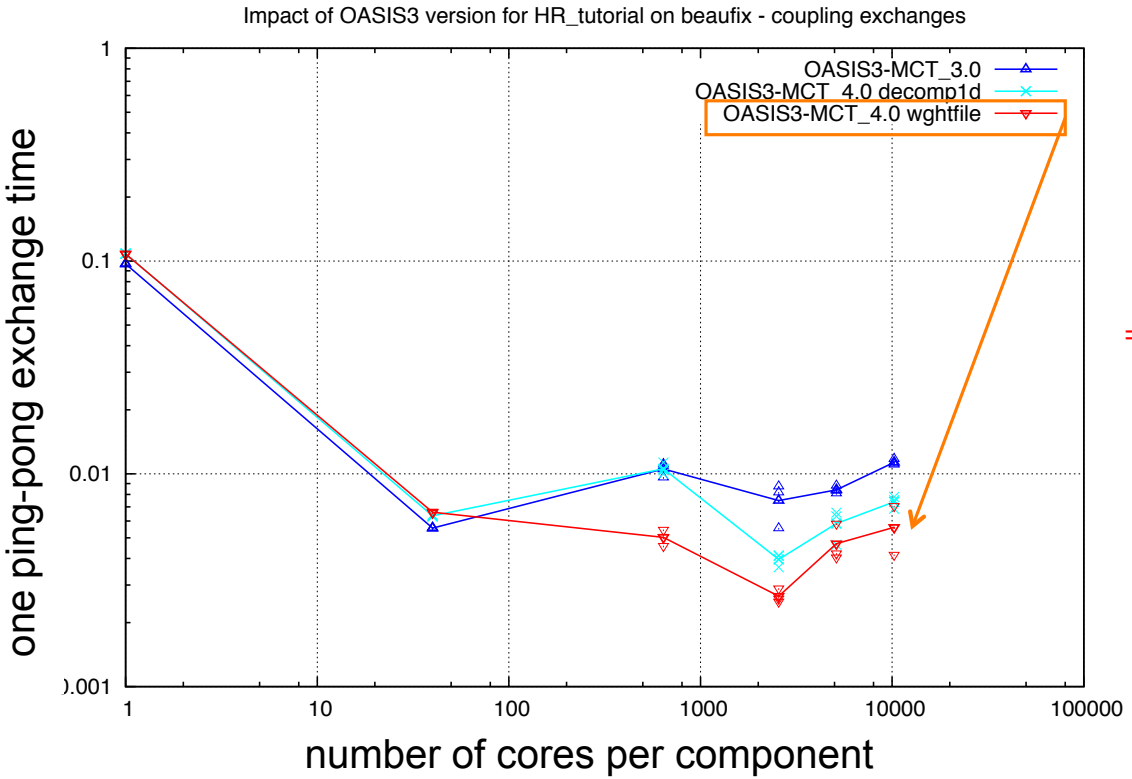
# Optimisation of the communication using the mapping weights

decomp_wghtfile



# Optimisation of the communication using the mapping weights

NEMO ORCA025 grid (1021x1442) –
Gaussian Reduced T799 grid (843 000)

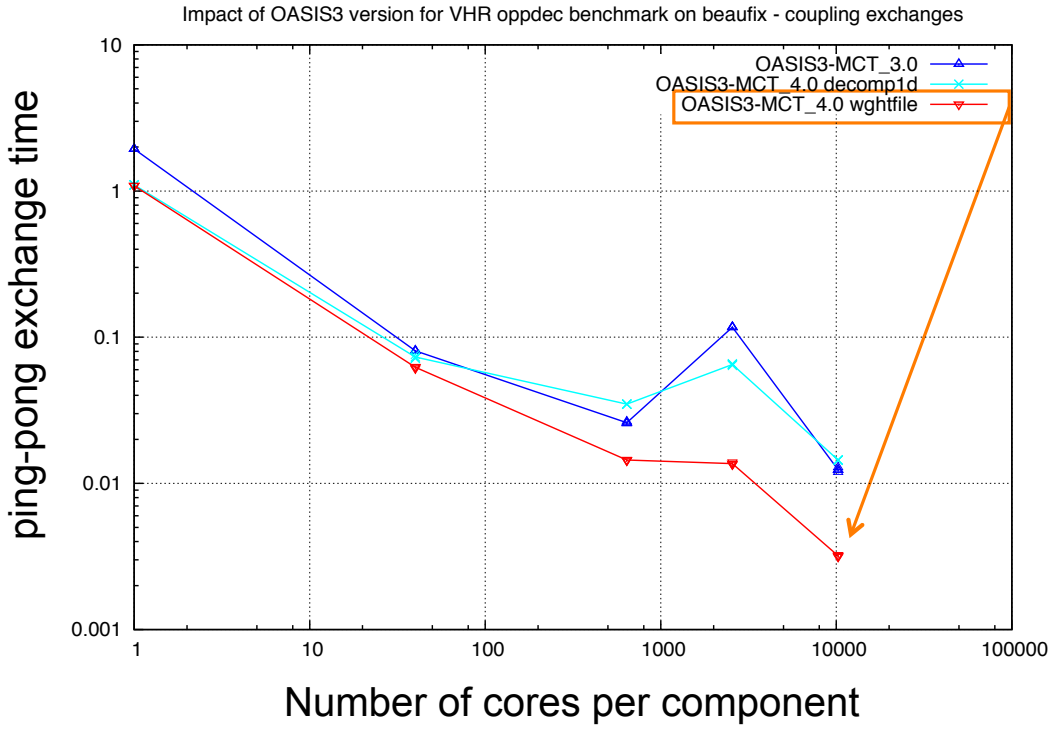



Results

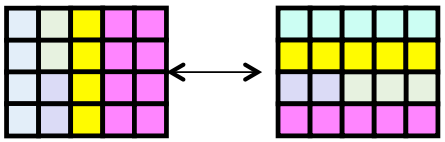
⇒ 24% reduction at 10240 cores for "decomp_wghtfile" wrt "decomp_1D" which is already 35% faster than OASIS3-MCT_3.0

# Optimisation of the communication using the mapping weights

IS-ENES benchmark VHR: 3000x3000
reg lat-lon grids, opposite decompositions




Results



⇒ 75% reduction in exchange time
at 10240 cores for that case

# Hybrid MPI+OpenMP parallelisation of the SCRIP library

## ➢ hybrid MPI+OpenMP parallelisation of the SCRIP library is now implemented

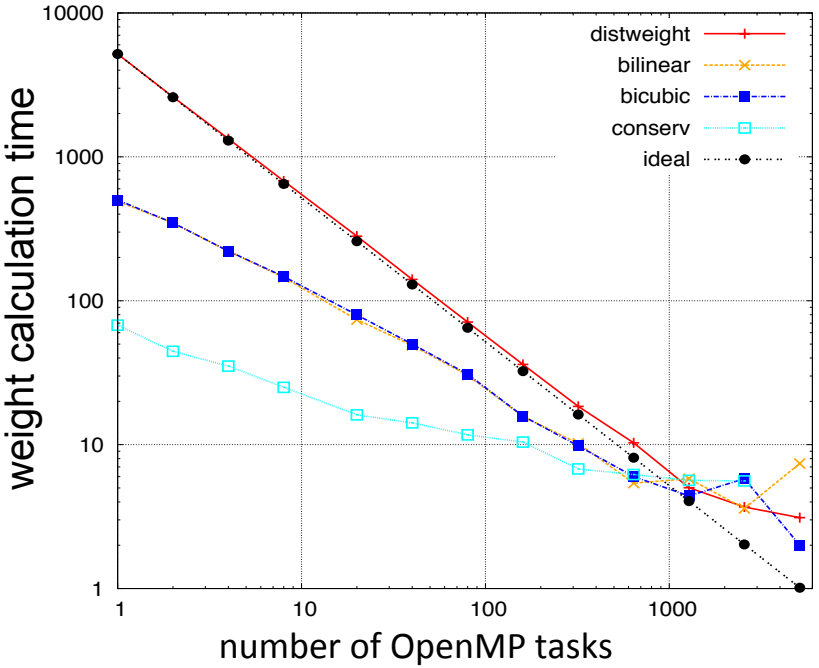
- hybrid MPI+OpenMP parallelisation:
  - one MPI process per node
  - OASIS_OMP_NUM_THREADS OpenMP threads per node (recommended: = number of cores/node)
- Parallelisation
  - over the outer loop on N target grid points for bicubic, distance-weighted and nearest-neighbour
  - over two outer loops over source and target grid cells for mesh border intersection for conservative remapping

**Code optimisation in sequential mode**

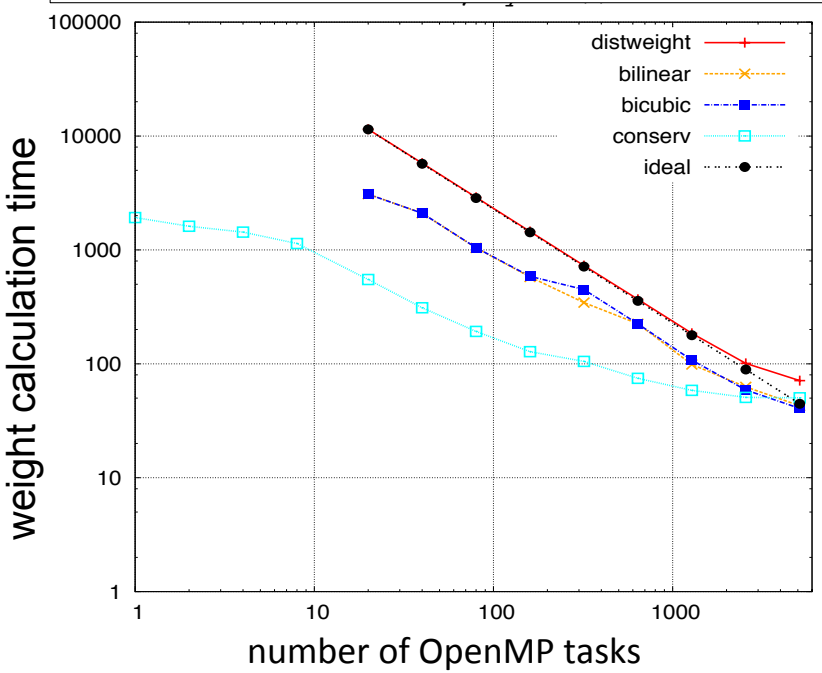
- detection of overlapping points (-DTREAT_OVERLAY): original algorithm $O(n^2)$ -> new algorithm $O(n \log(n))$
  - ➢ orca025 to t359 remapping : 731 sec -> 0.4 sec
- complementary non-masked nearest neighbour for target cells without in any conservative link (FRACNNEI) :
  - ➢ T359 to ORCA025 coupling : 293 sec -> 5.9 seconds

# Hybrid MPI+OpenMP parallelisation of the SCRIP library

ORCA025 (1442x1050) – T359 (181724)



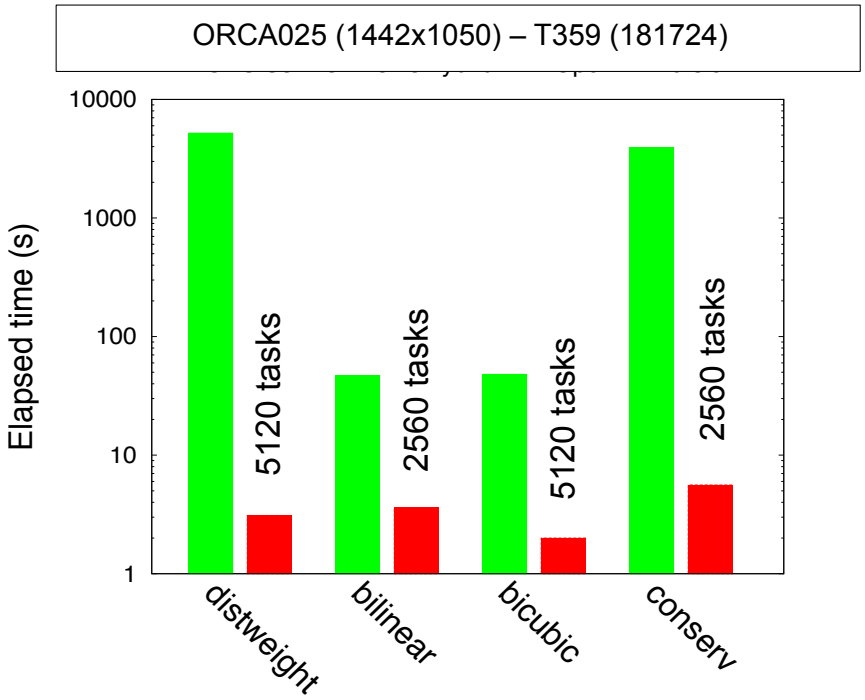

ORCA12 grid (4322x3147) – T799 grid (843490)

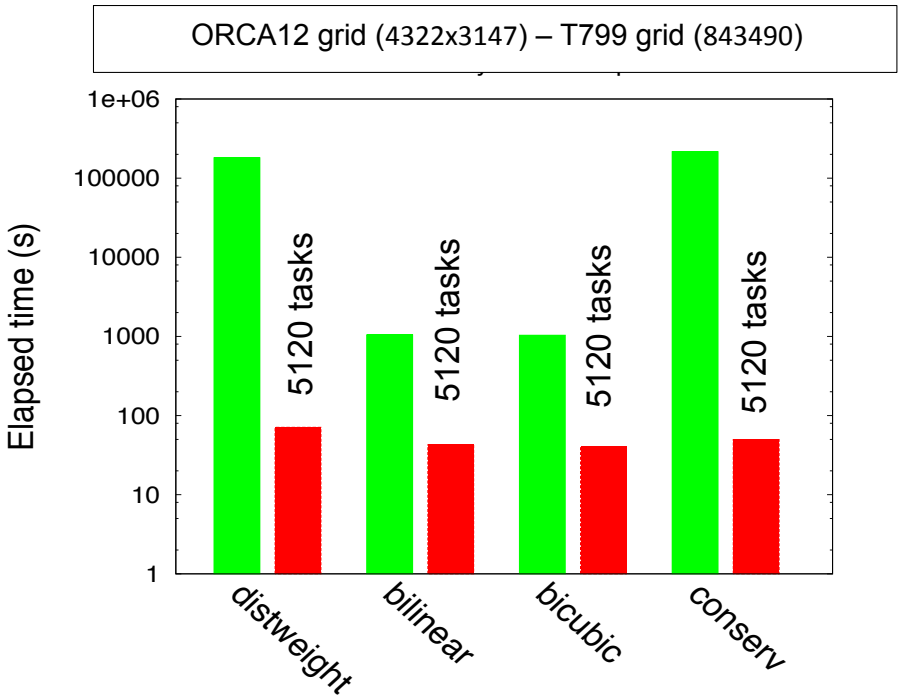



- Almost perfect scalability for nearest-neighbour and bilinear (-> 1280 tasks for HR;-> 2560 tasks for VHR)
- Good scalability for bicubic remapping
- Less scalability for conservative remapping, due to better sequential performance (bin restriction)

# Hybrid MPI+OpenMP parallelisation of the SCRIP library

OASIS3-MCT_3.0 vs OASIS3-MCT_4.0 MPI+OpenMP hybrid best performance

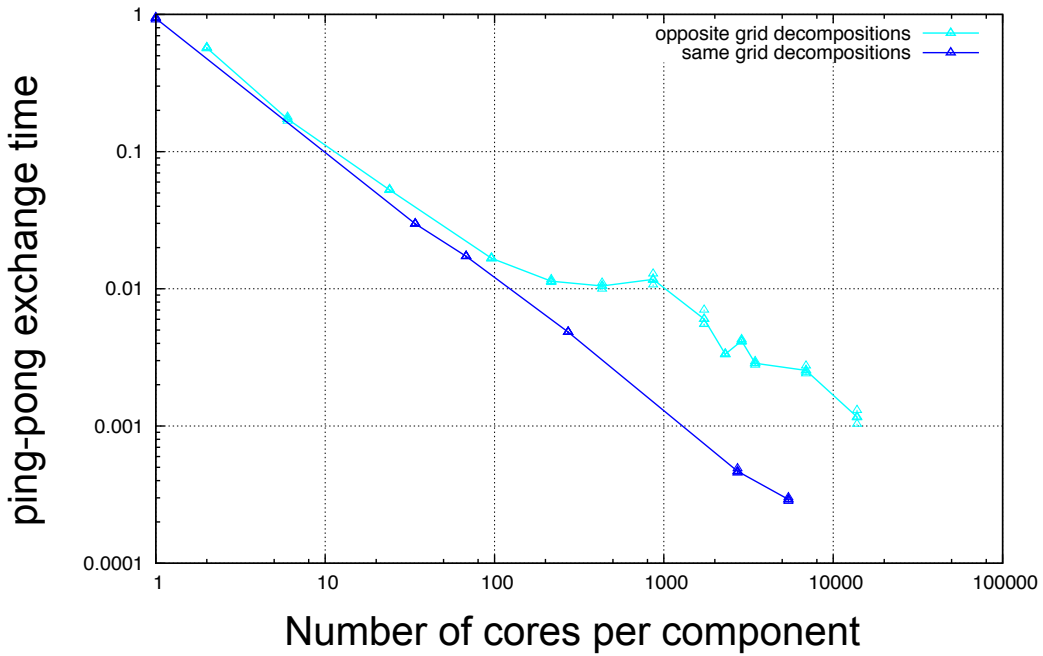



- reduction in the weight calculation time of 2 or 3 orders of magnitude

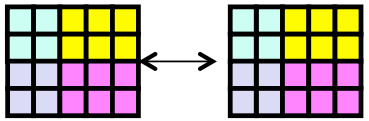
# Performance of IS-ENES2 coupling benchmark with OASIS3-MCT_3.0 on Marconi KNL

- allocation of 390 000 core hours granted to ESiWACE CoE

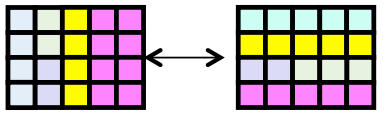



VHR: 3000x3000 reg lat-lon grids

same decomposition



opposite decomposition



- almost perfect scalability for up to O($10^4$) cores/tasks per component for VHR
- very reasonable behaviour for the VHR_oppdec;
- would probably be better with OASIS3-MCT_4.0 decomp_wghtfile


# From OASIS3-MCT_3.0 to OASIS3-MCT_4.0

## OASIS3-MCT_4.0 released before the summer with many performance improvements:

- "nointerp" option: bypassing the identity matrix multiplication:
  - OASIS3-MCT as good as other coupling technologies for the IS-ENES2 benchmark VHR test case
- New global conservation method *reprosum*:
  - ~bit-for-bit reproducibility, O(10) less costly than previous *bfb* method
- Upgrade from MCT 2.8 to MCT 2.10.beta1
  - significant reduction of the initialisation cost
- Bugfix : removal of concurrent writing into the OASIS3-MCT debug files at initialization
  - drastic reduction of the initialisation cost
- New way to define the intermediate mapping decomposition based on remapping weights (decomp_wghtfile)
  - significant gain at run time
- Hybrid MPI/OpenMP parallel SCRIP library
  - reduction in the weight calculation time of 2 or 3 orders of magnitude for high-resolution grids
  - opens the door to runtime weight computation dynamical coupling with OASIS3-MCT

Thank you for your attention !