



OASIS3-MCT, a coupler for climate modelling

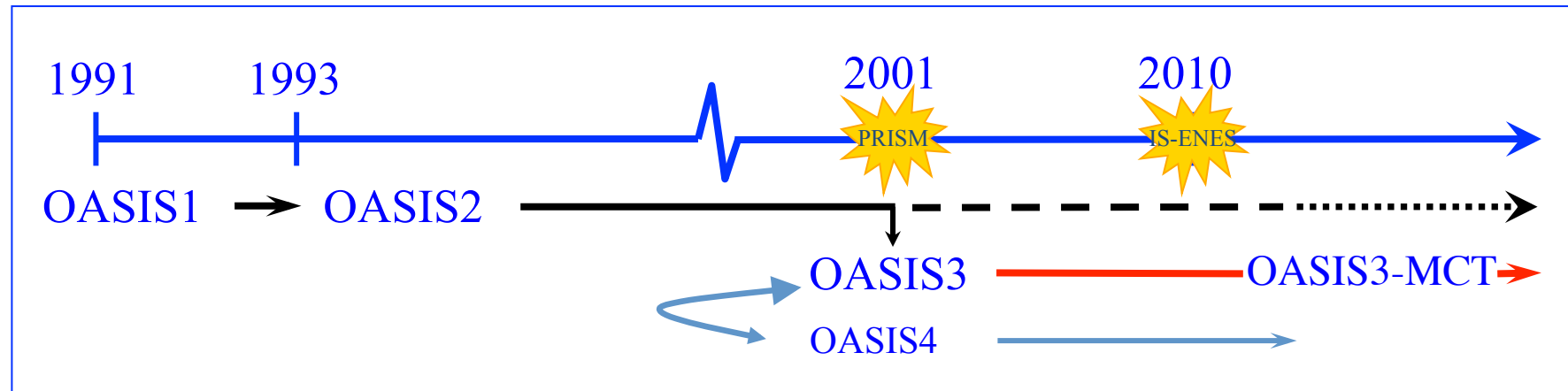
S. Valcke, CERFACS

- OASIS historical overview
- OASIS3-MCT:
 - Application Programming Interface
 - Parallel Decompositions supported
 - Communication
 - Interpolations et transformations
 - Users
 - Performance
- Conclusions and perspectives





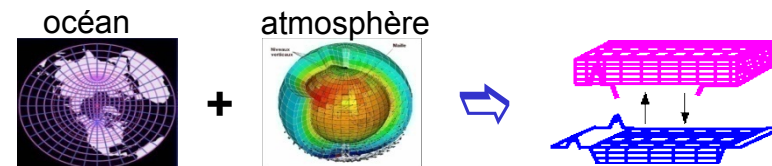
OASIS historical overview



• OASIS1 -> OASIS2 -> OASIS3:

2D ocean-atmosphere coupling
low resolution, low frequency

→ flexibility, modularity, 2D interpolations

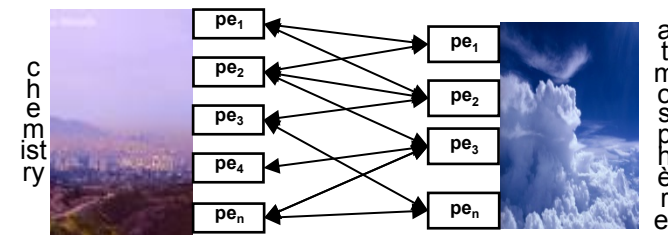


❖ 35 user groups world-wide, used by 6 of the 7 European Earth System Modelling groups

• OASIS4 / OASIS3-MCT:

2D/3D coupling of high resolution parallel components on massively parallel platforms

→ parallelism, efficiency, performance





OASIS historical overview

OASIS4

- Developed by CERFACS, CNRS, DKRZ and MPI-M (PRISM & IS-ENES EU projects)
- Fully parallel generation of regridding weights & addresses
- Specific OASIS4 versions used in:
 - 3D coupling between atmosphere and atmospheric chemistry at ECMWF, KNMI and Météo-France (EU GEMS & MACC projects)
 - SMHI (Sweden) for regional ocean-atmosphere in the Arctic
 - BoM (Australia) for global ocean-atmosphere coupling
- Development was stopped in July 2011:
 - Lack of resources for development of real-time parallel calculation of regridding weights and addresses for all type of grids
 - OASIS4 code too complex to evolve easily and original design did not include unstructured grids
- Take a step back:
 - Suppose that (static) weights & addresses are pre-calculated before the run
 - Use MCT in OASIS3 for // reading of weights & addresses, // computation of communication patterns, // matrix multiplication, // data transfer & redistribution



OASIS3-MCT

- First official version released in August 2012
- Uses the Model Coupling Toolkit (MCT) from Argonne National Lab
- Open source, LGPL license, F90 and C
- External libraries: public domain (MPI, NetCDF) or open source (SCRIP, MCT)
- Current developers are:
 - 2 permanent FTEs (CERFACS, CNRS)
 - 1 consultant (T. Craig, also NCAR CESM cpl7 developer)



IS-ENES (InfraStructure for ENES) EU FP7 project
2009-2012 - 18 partners - 7,6 MEuros ; coord: IPSL

- 93 pm for OASIS development and support



IS-ENES2, EU FP7 project 2013-2016 - 25 partners -
8MEuros; coord: IPSL

- 27 pm for OASIS3-MCT development and support



OASIS3-MCT Application Programming Interface

- ◆ Component models remain separate executables
- ◆ OASIS3-MCT acts as a communication library linked to the models
- ◆ OASIS3-MCT API is strictly backward compatible with OASIS3.3 API

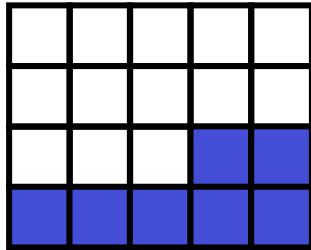
```
•Initialisation:          call oasis_init_comp(...)  
•Grid definition:        call oasis_write_grid (...)  
•Local partition definition: call oasis_def_partition (...)  
•Coupling field declaration: call oasis_def_var (...)  
  
•Coupling field exchange (in model time step loop) :  
    call oasis_put (... , date, var_array. ...)  
    call oasis_get (... , date, var_array, ...)  
    ➤ all coupling parameters defined externally by the user in a text file  
      • source or target (end-point communication)  
      • 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 (...)
```



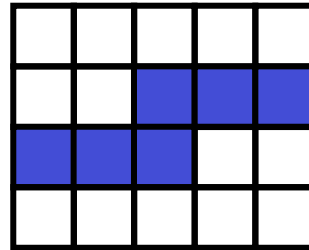
OASIS3-MCT: parallel decomposition supported

Apple

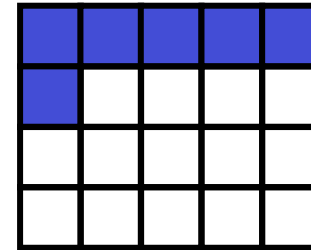
part1



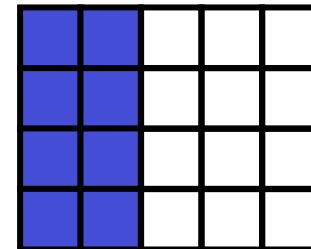
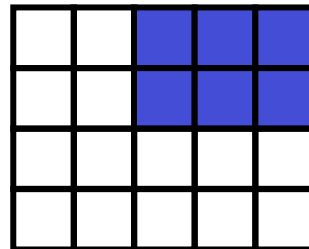
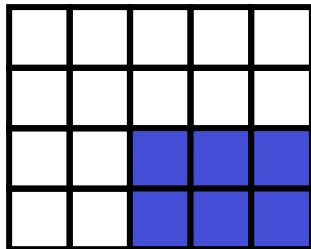
part2



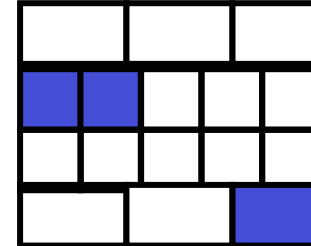
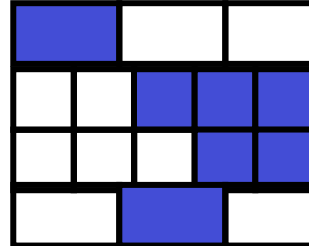
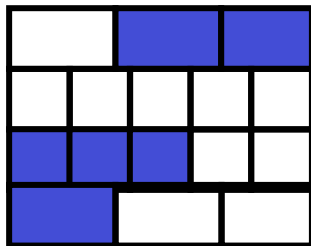
part3



Box



Orange



Apple and orange applicable to unstructured grids

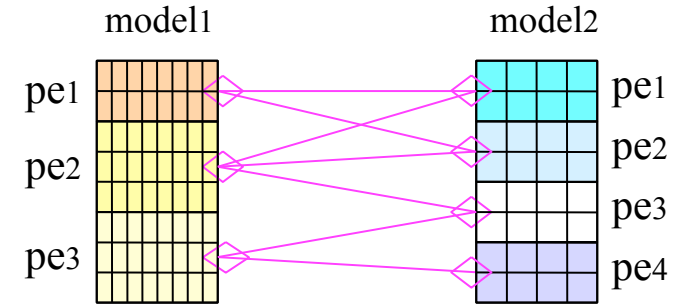


OASIS3-MCT communication

Fully parallel communication between parallel models based on MCT using MPI:



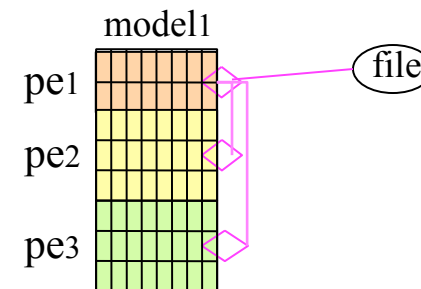
- computation of communication patterns
- reading of weights & address files
- matrix multiplication for regridding
- data transfer/redistribution



If required, the regridding weights and addresses are calculated onto one model process using the LANL SCRIP library

Regridding per se from the source grid to the target grid can be done on the source or on the target processes

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





OASIS3-MCT: interpolations & transformations

- on 2D or 3D scalar fields
- on different types of grids: lat-lon, rotated (logically rectangular), gaussian reduced, unstructured

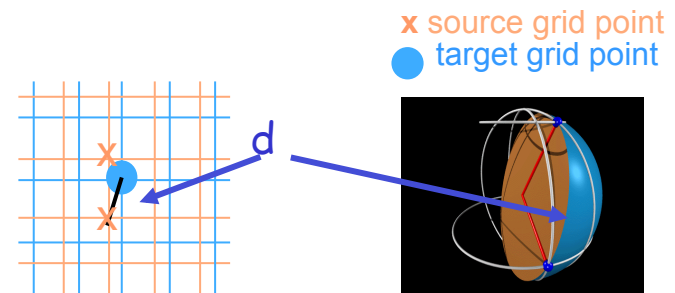
❖ Transformations

- Statistics
- Addition/multiplication by scalar
- Global conservation

❖ Interpolations/regridding

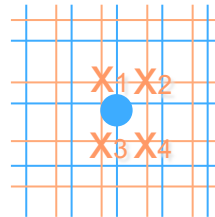
SCRIP library (Jones, 1999)

- n-nearest-(gaussian-weighted)-neighbours: $\text{weight}(x) \propto 1/d$
d: great circle distance on the sphere:



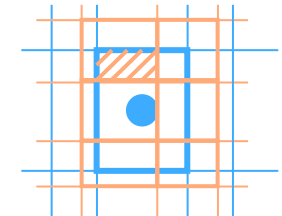
- bilinear interpolation

- general bilinear iteration in a continuous local coordinate system using $f(x)$ at x_1, x_2, x_3, x_4



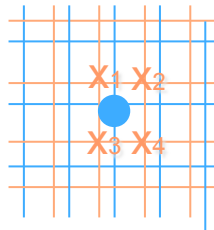
- conservative remapping

- weight of a source cell % to intersected area

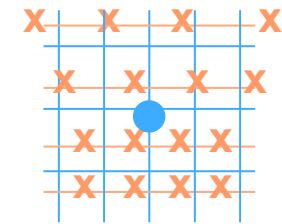


- bicubic interpolation:

- general bicubic iterations in a continuous local coordinate system: $f(x), \delta f(x)/\delta i, \delta f(x)/\delta j, \delta^2 f/\delta i \delta j$ in x_1, x_2, x_3, x_4 for logically-rectangular grids (i,j)



- standard bicubic algorithm: **16 neighbour points** for Gaussian Reduced grids



** gradients must be given as extra arguments to the oasis_put

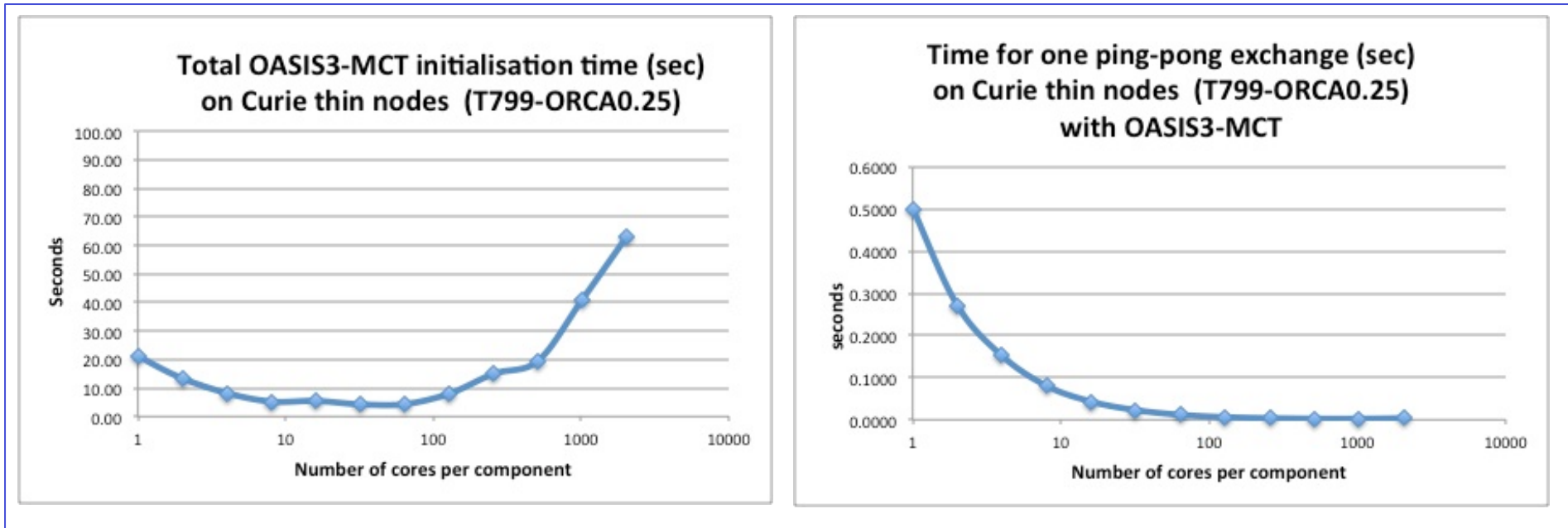


OASIS3-MCT users

- ◆ CERFACS (France): running
 - NEMO ocean (ORCA025, 1021x1442) - ARPEGE atmosphere (Gaussian Red T359 grid, 181724 points).
 - Seasonal prediction experiments in SPRUCE project, (27 Mhours on PRACE tier-0 Bullx Curie).
 - ◆ IPSL (France): running (some problems at 8000 cores?)
 - WRF atm - NEMO ocean model, both with two-way nested zooms, resolution from 27 km to 9 km.
 - Used in PULSATION project funded by the French ANR, 22 Mhours on PRACE tiers-0 Bullx Curie.
 - ◆ MPI-M (Germany): running but not fully validated
 - All MPI-ESM versions, in particular MPI-ESM-XR: atmosphere ECHAM6 T255L95 (768x384 grid points, ~50km, 95 vertical levels) - ocean MPIOM TP6ML40 (3602x2394 grid points, ~10km, 40 vertical levels); 17 coupling fields, 1h coupling frequency.
 - ◆ MetOffice (UK) : running (some adaptations needed when I/O server on?)
 - Global ocean-atmosphere coupling between UM global atmosphere (N512, 1024x769) and NEMO ocean (ORCA025, 1021x1442).
 - ◆ BTU-Cottbus (Germany): running
 - 3D coupling between COSMO-CLM regional atmosphere (221x111x47, ~2 deg) and ECHAM global atmosphere (T63, 192x96x47), + 2D coupling to MPI-OM ocean (254x220)
 - 6% coupling overhead observed for exchange of 6 x 3D fields every ECHAM time step
 - ◆ BoM (Australia): under developments
 - limited area coupled model MOM4p1 ocean and UK Met Office UM6.4 atmosphere.
 - ◆ ...
-



OASIS3-MCT performance



- Bullx Curie thin nodes; for each node: 2 eight-core Intel® processors Sandy Bridge EP (E5-2680) 2.7 GHz; Intel Fortran 12.1.7.256, Bullx MPI 1.1.16.5
- Toy coupled model: ping-pong exchanges between one component on NEMO ORCA025 grid (1021x1442) and the other on a Gaussian Reduced T799 grid (843 000 grid points)
- Coupling overhead for:
 - one-year long simulation with one 1 coupling exchange every hour in each direction
 - components with $O(1\text{ M})$ grid points running on 2000 cores/component
 - ◆ ~60 seconds for initialisation, ~30 seconds for data exchange
 - ◆ (previous OASIS3.3 would have taken ~2600 seconds for the same data exchanges)



Conclusions and perspectives

Conclusions on OASIS3-MCT

- Good performance, removes OASIS3.3 bottleneck
- Very simple to use for traditional OASIS3.3 users (same API)
- > OASIS3-MCT most likely provides a satisfactory solution for fully parallel coupling in our climate models at the resolutions targeted operationally for the next ~5 years.

** An excellent example of shared software and Coupling Workshops benefits **

Perspectives:

- Refactoring of *namcouple* configuration file
- Evaluation of ESMF for off-line precomputing of interpolation weights (on going)
- Evaluation of Open-PALM (including ONERA CWIPI library) for on-line parallel calculation of interpolation weights (designed for unstructured grid)
- IS-ENES2:
 - Coupling technology benchmark (Thursday afternoon session)
 - Should we (Europeans) evolve to the "integrated mono-executable" approach (e.g. CESM, GFDL, ESMF: more constraints but more opportunities for performance, e.g. exchange of coupling data through the memory)?



The end



OASIS community today

About 35 groups world-wide (climate modelling or operational monthly/seasonal forecasting):

- France: CERFACS, METEO-FRANCE, IPSL (LOCEAN, LMD, LSCE), OMP, LGGE, IFREMER
 - Europe: ECMWF + Ec-Earth community
 - Germany: MPI-M, IFM-GEOMAR, HZG, U. Frankfurt
 - UK: MetOffice, NCAS/U. Reading, ICL
 - Denmark: DMI
 - Norway: U. Bergen
 - Sweden: SMHI, U. Lund
 - Ireland: ICHEC, NUI Galway
 - The Netherland: KNMI
 - Switzerland: ETH Zurich
 - Italy: INGV, ENEA, CASPUR
 - Czech_Republic :CHMI
 - Spain: U. Castilla
 - Tunisia: Inst. Nat. Met
 - Japan: JMA, JAMSTEC
 - China: IAP-CAS, Met. Nat. Centre, SCSIO
 - Korea: KMA
 - Australia: CSIRO
 - New Zealand: NIWA
 - Canada: RPN-Environment Canada, UQAM
 - USA: Oregon State U., Hawaii U., JPL, MIT
 - Peru: IGP
- OASIS3 is used in 5 European ESMS that participate in IPCC AR5
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Use of OASIS3-MCT

At run time, the component models remain separate executables and OASIS3-MCT acts as a communication library linked to the models.

To use OASIS3-MCT:

- Register, download the sources, compile and run the tutorial toy model on your platform
- Identify your component models, their grids, the coupling fields to be exchanged between those models
- Identify the interpolations/transformations needed to go from the source to the target grid
- Use the "test_interpolation" environment (offline interpolations/transformations) to test their quality
- Adapt your model i.e. insert calls to OASIS3-MCT communication library
- Choose the other coupling parameters (source and target, frequency, field transformations, etc.) and write the full *namcouple* configuration file
- Compile OASIS3-MCT and link the components models with it
- Start the models and let OASIS3-MCT manage the coupling exchanges