CROCO and Parallelisation : an overview

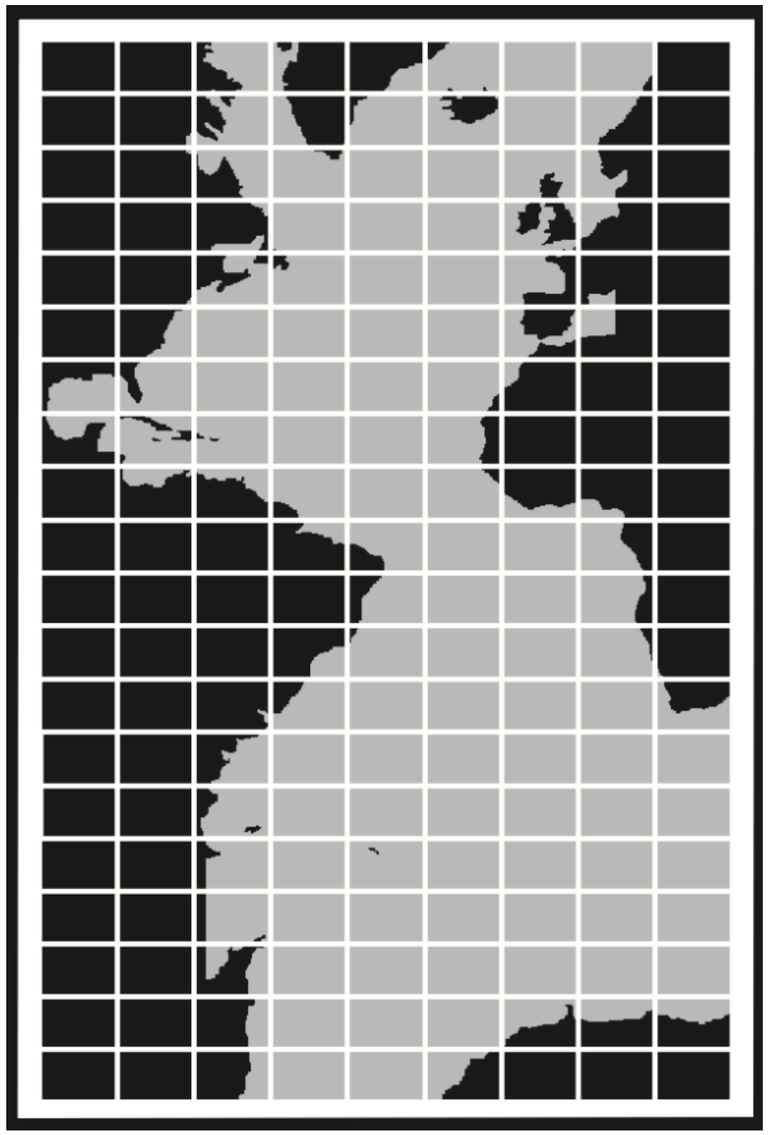
Rachid Benshila

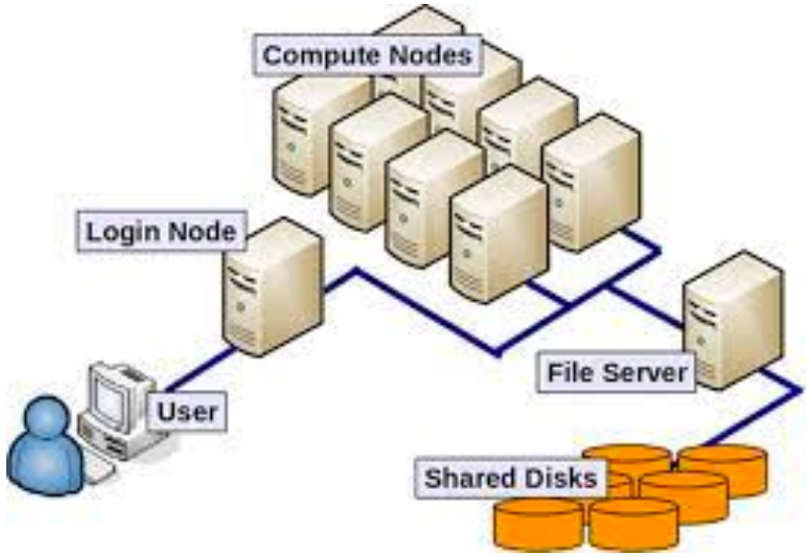
Concept and techniques

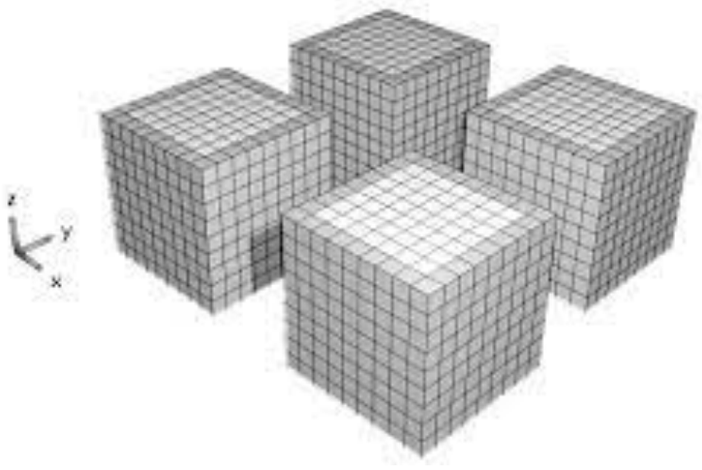
How to use

Related aspects

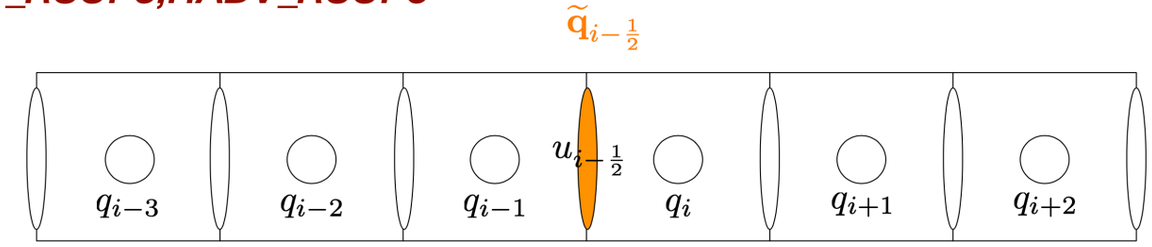
Parallelisation : domaine decomposition



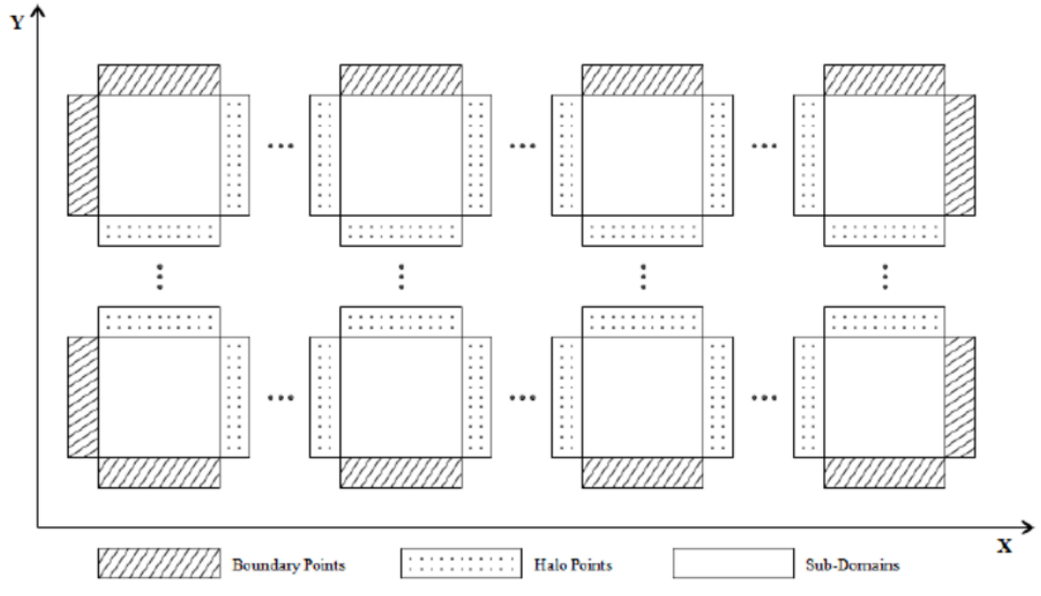




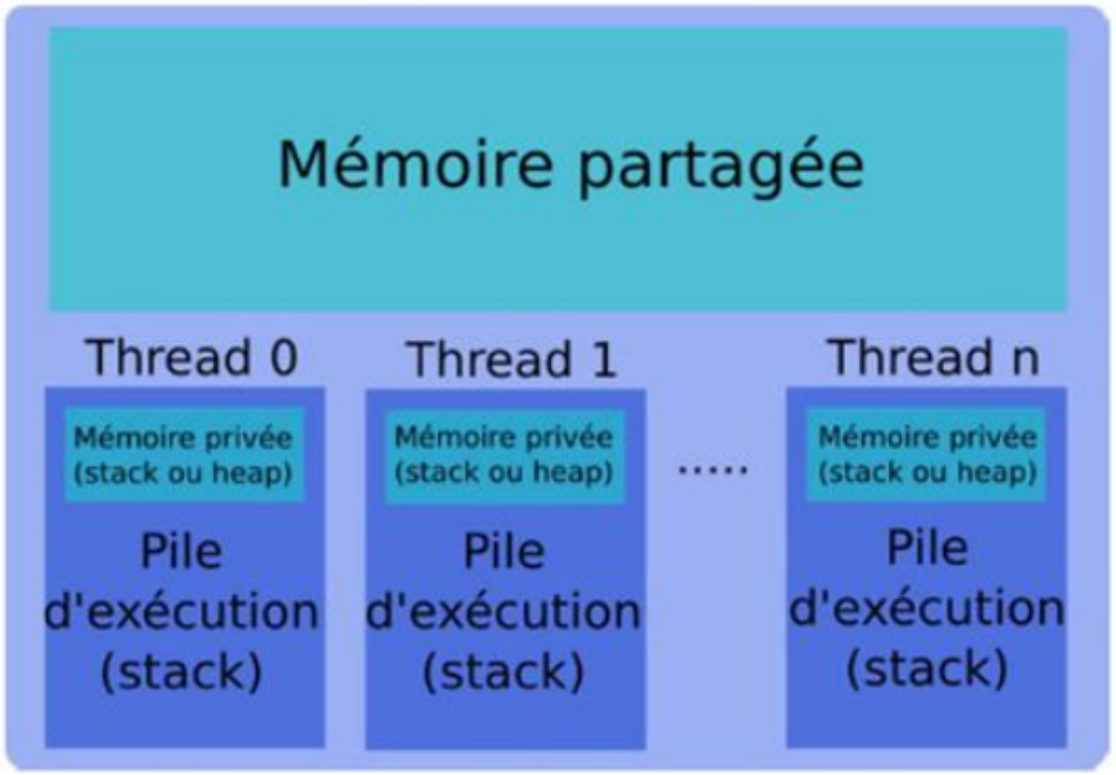
HADV_RSUP3,HADV_RSUP5

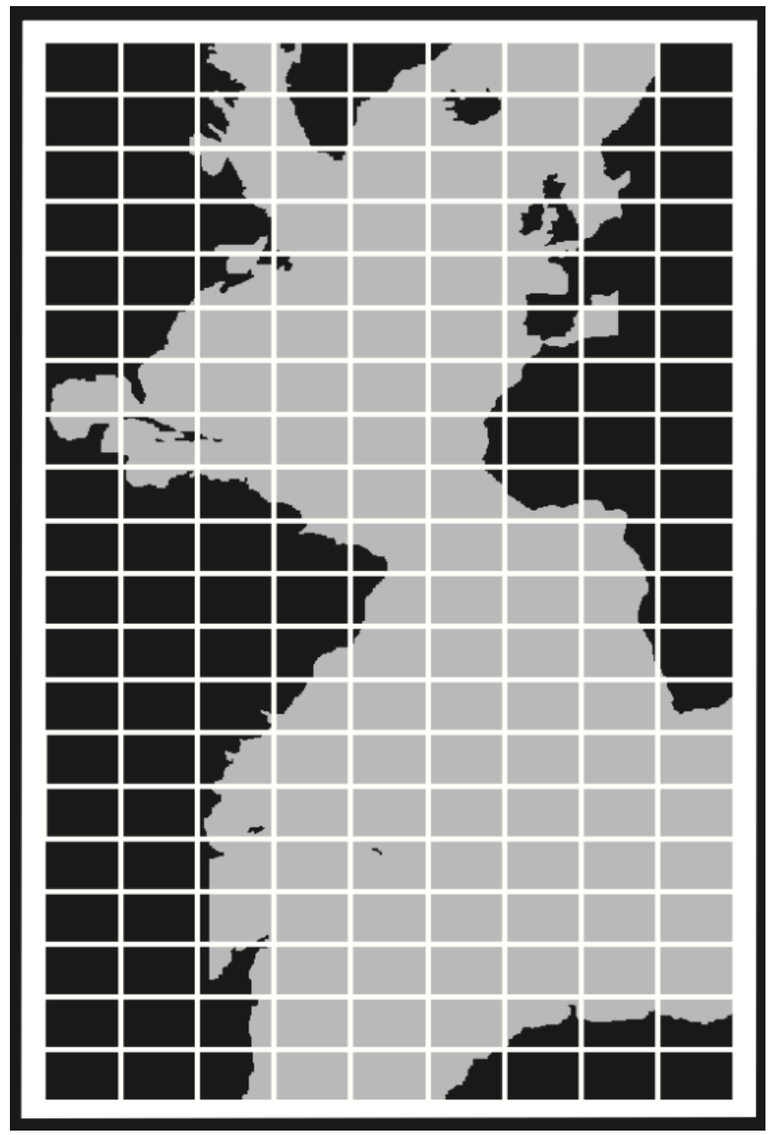


$$\partial_x(uq)|_{x=x_i} = \frac{1}{\Delta x_i}\left\{u_{i+\frac{1}{2}}\widetilde{q}_{i+\frac{1}{2}} - u_{i-\frac{1}{2}}\widetilde{q}_{i-\frac{1}{2}}\right\}$$



Approach 1 : shared memory

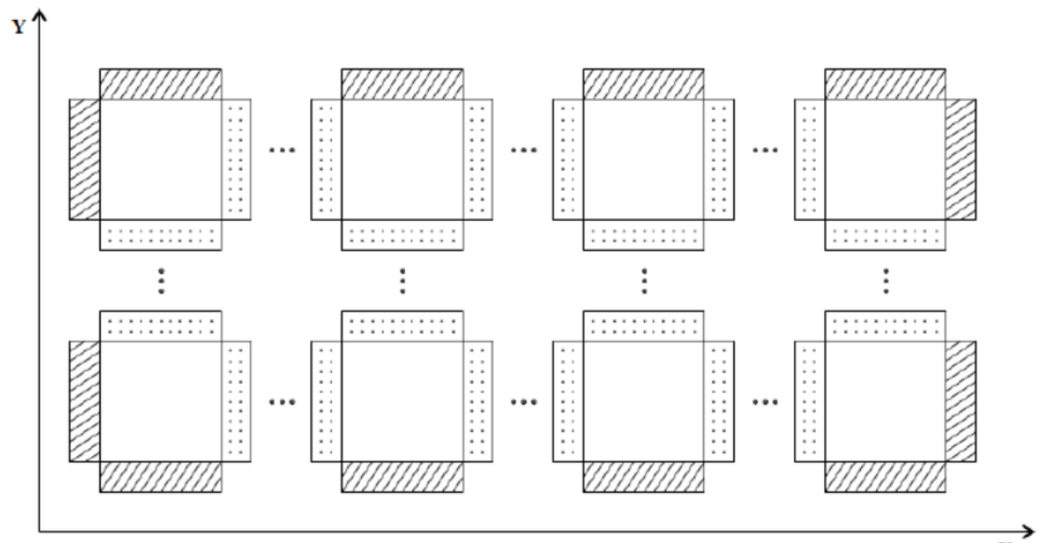




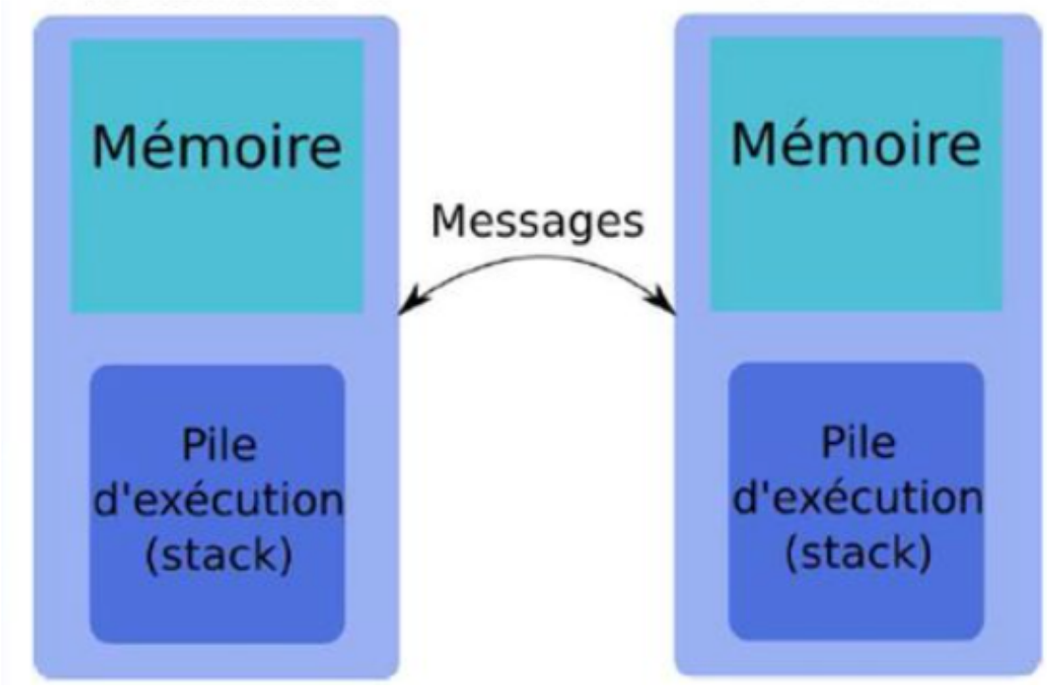
=> cores have access to a common shared memory

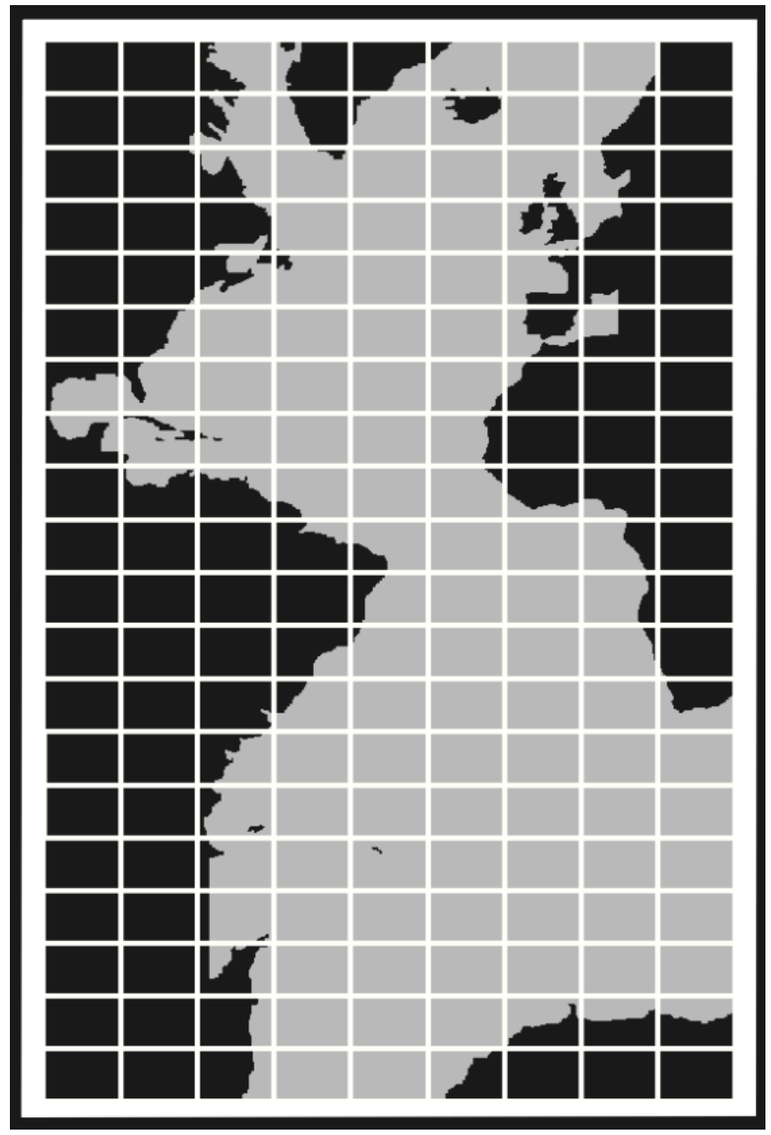
=>exchange of information through memory copy

Standard OpenMP
(Open Multi-Processing)



Approach 2 : distributed memory

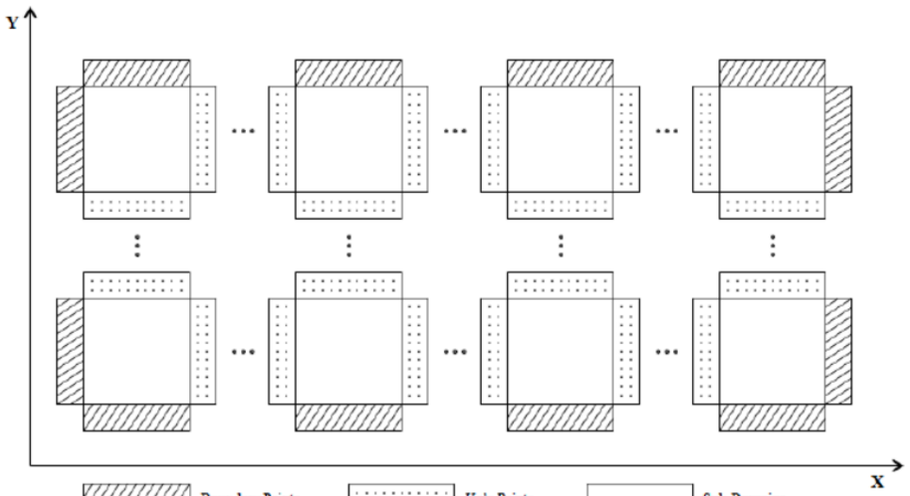




=> cores don’t have access to a common memory

=> exchanges through network and interconnection

=> in practice MPI can handle efficiently shared memory



Standard MPI
(Message Passing Interface)

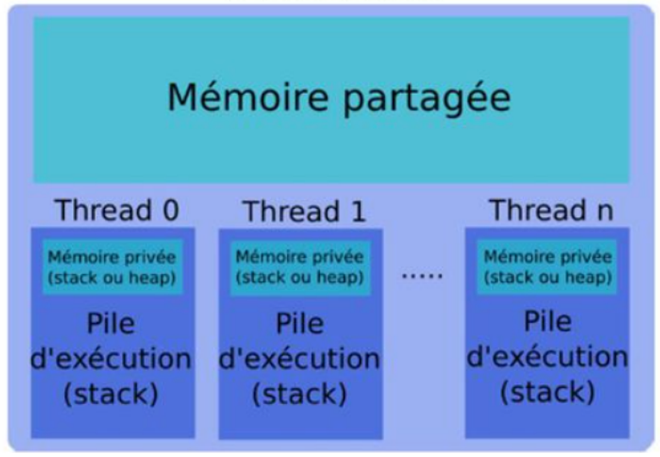
Implementation within CROCO : OPENMP

- step 1 : 2 files to edit
  - param.h
    specify the decomposition
    in x et y directions => NPP=4
  - cppdefs.h :
    activate OpenMP. => *#define OPENMP*

```
!
! Domain subdivision parameters
! ====== =========== ==========
!
! NPP             Maximum allowed number of parallel threads;
! NSUB_X,NSUB_E   Number of SHARED memory subdomains in XI- and
!                                                 ETA-directions;
! NNODES         Total number of MPI processes (nodes);
! NP_XI,NP_ETA   Number of MPI subdomains in XI- and ETA-directions;
!
      integer NSUB_X, NSUB_E, NPP
#ifdef MPI
      integer NP_XI, NP_ETA, NNODES
      parameter (NP_XI=1,  NP_ETA=4,  NNODES=NP_XI*NP_ETA)
      parameter (NPP=1)
      parameter (NSUB_X=1, NSUB_E=1)
#elif defined OPENMP
      parameter (NPP=4)
# ifdef AUTOTILING
      common/distrib/NSUB_X, NSUB_E
# else
      parameter (NSUB_X=1, NSUB_E=NPP)
# endif
#else
      parameter (NPP=1)
```

- step 2 : compilation
  ./jobcomp

- étape 3 : execution
  - export OMP_NUM_THREADS=4
    specify the number of cores for the environment
  - ./croco



Implementation within CROCO : MPI

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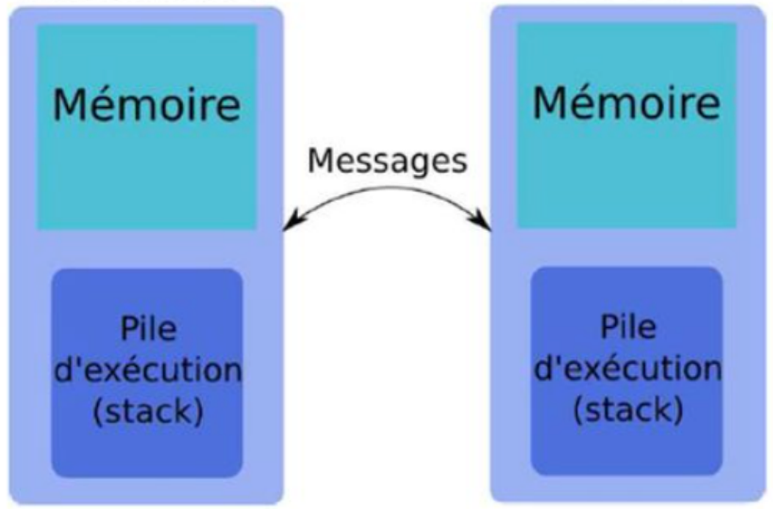
```

- step 2 : compilation
  ./jobcomp

- étape 3 : compilation
  - mpirun -n 4 ./croco
    (or mpiexec or ….)



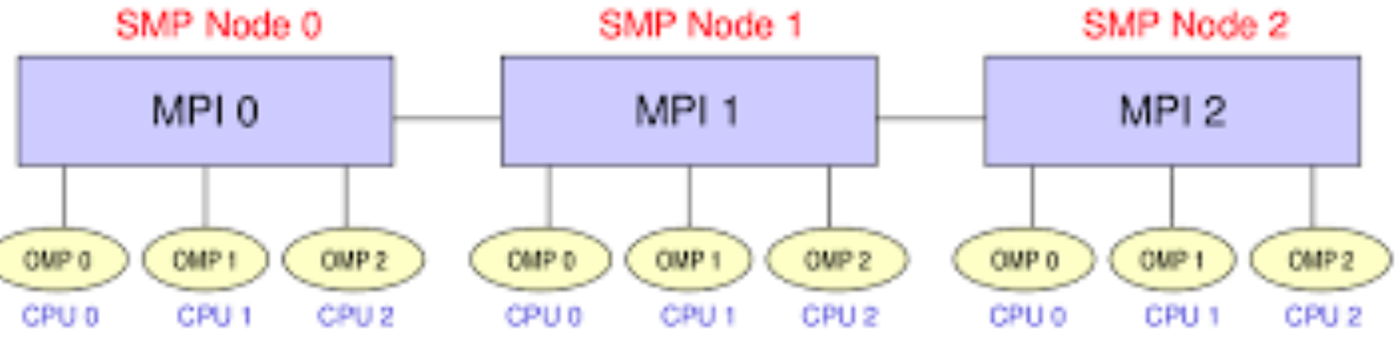
Summary and perspectives

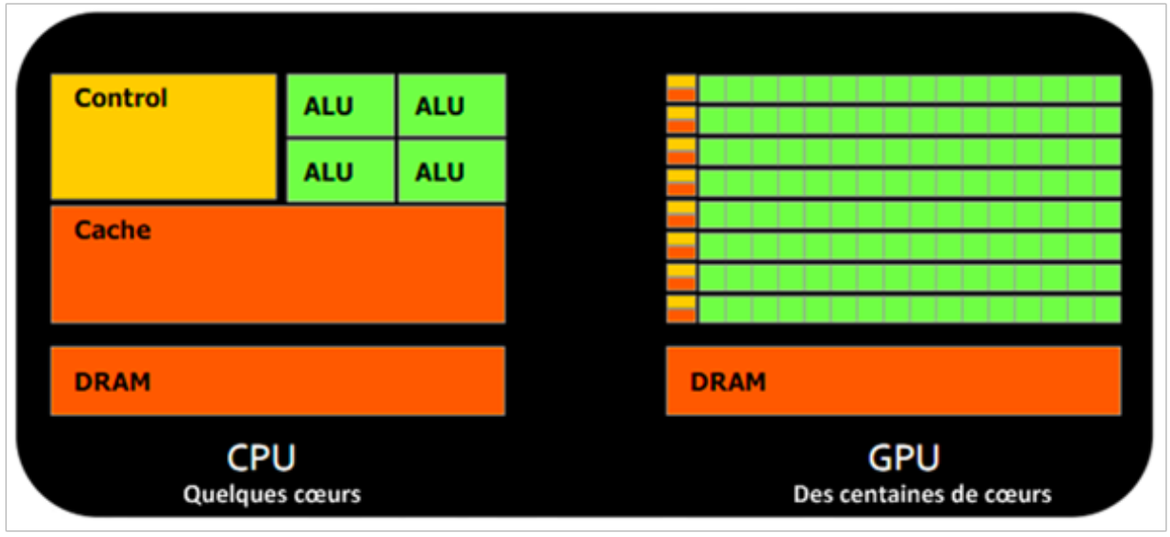
- 2 paradigmes available MPI et OpenMP

- code to re-compile !!

- MPI currently more used for Croco

- ETA direction for decomposition





no hybrid MPI/OpenMP

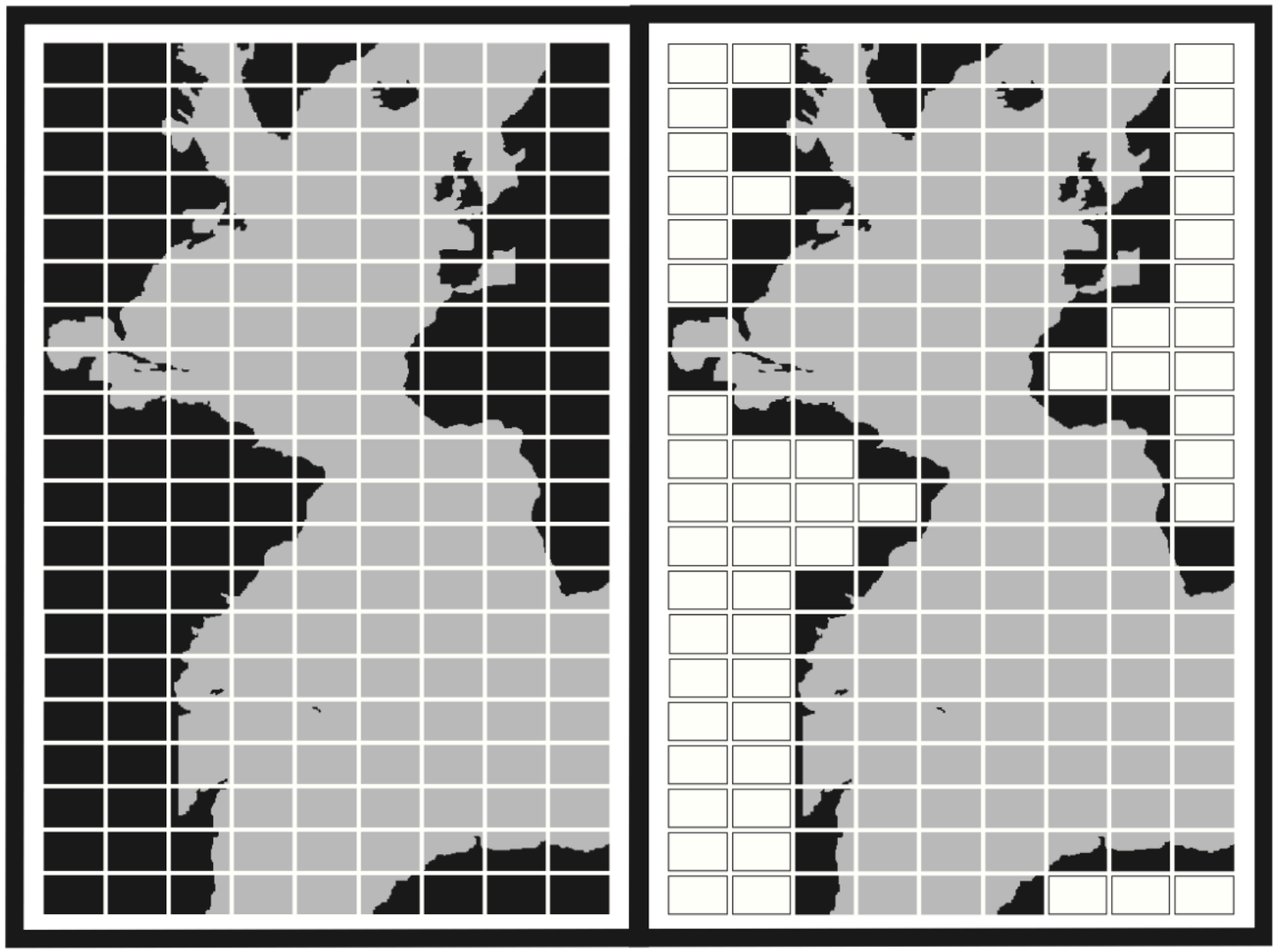
GPU version underway

Parallelisation : but also ....

A few tricks :

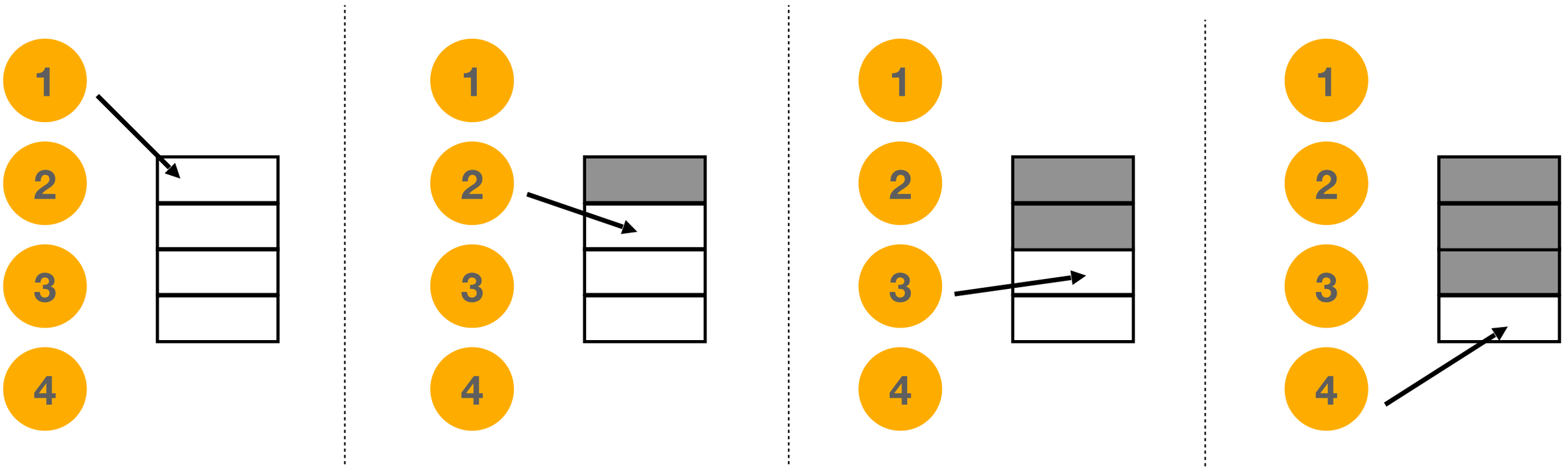
- the output files case (MPI)

- the land only processors case



MPI => Writing files 1/4 : default

mpirun -np 4 ./croco. (NP_ETA=4)

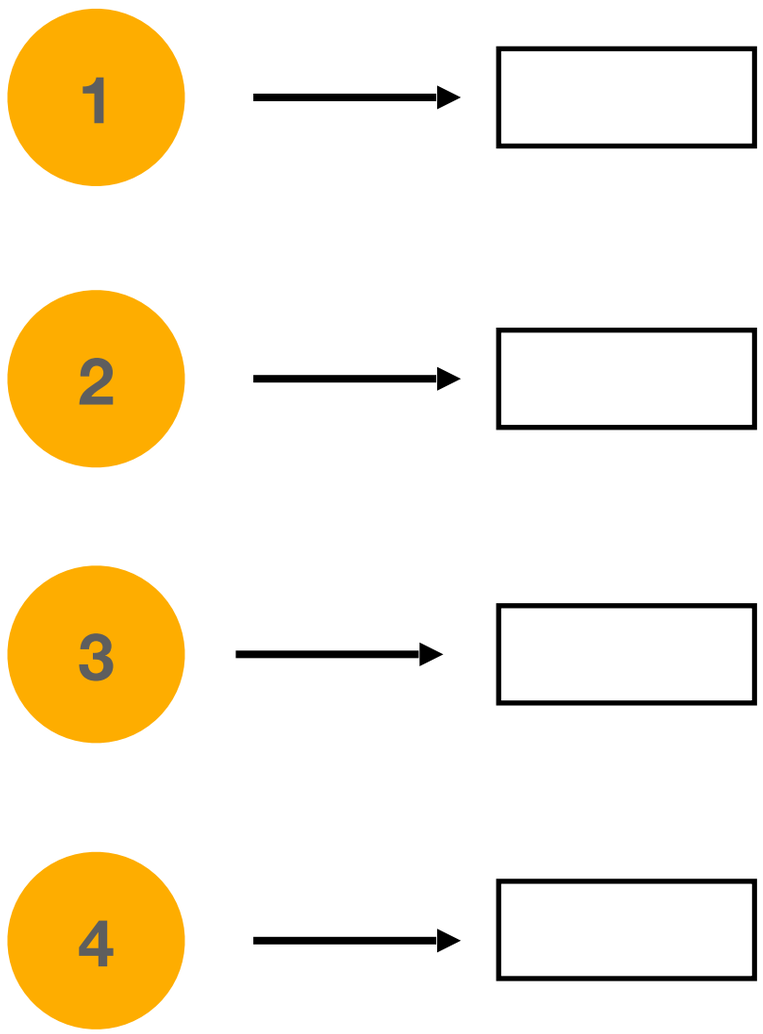


Unefficient !!!!!!!

MPI => Writing files 2/4 : parallel files

#define PARALLEL_FILES

mpirun -np 4 ./croco. (NP_ETA=4)



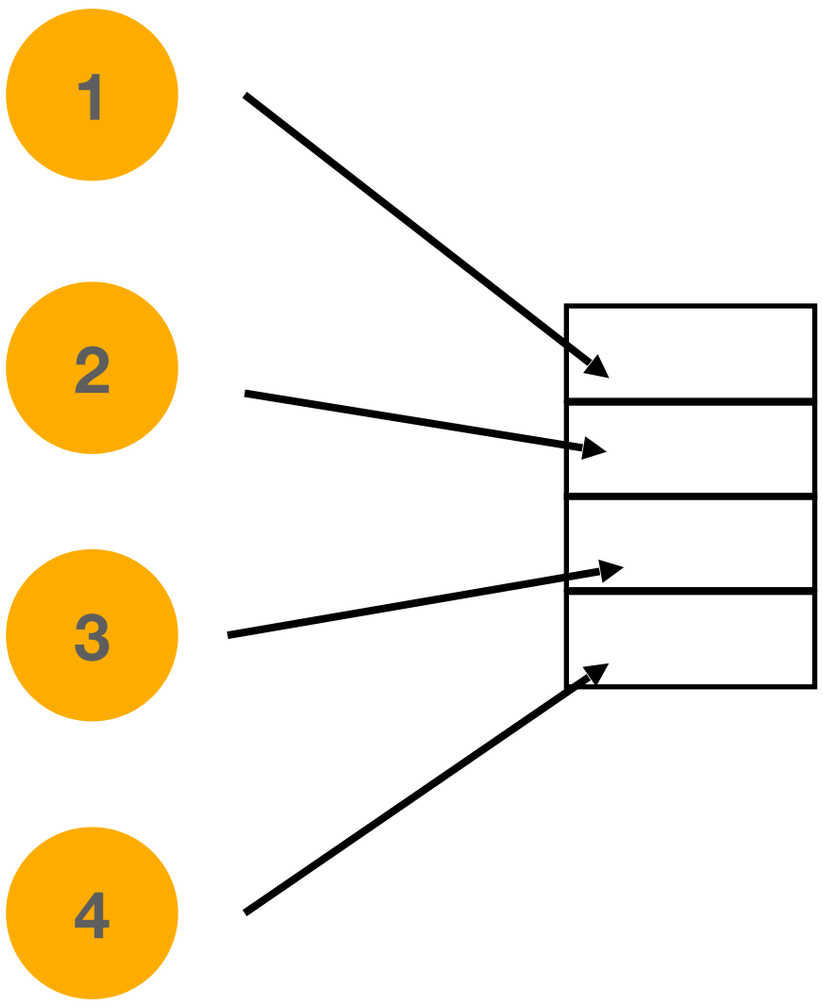
Fast but a lot of small files at the end

Need to reconstruct a global file (cf utility ncjoin)

MPI => Writing files 3/4 : parallel writing

#define KEY NC4PAR

mpirun -np 4 ./croco. (NP_ETA=4)

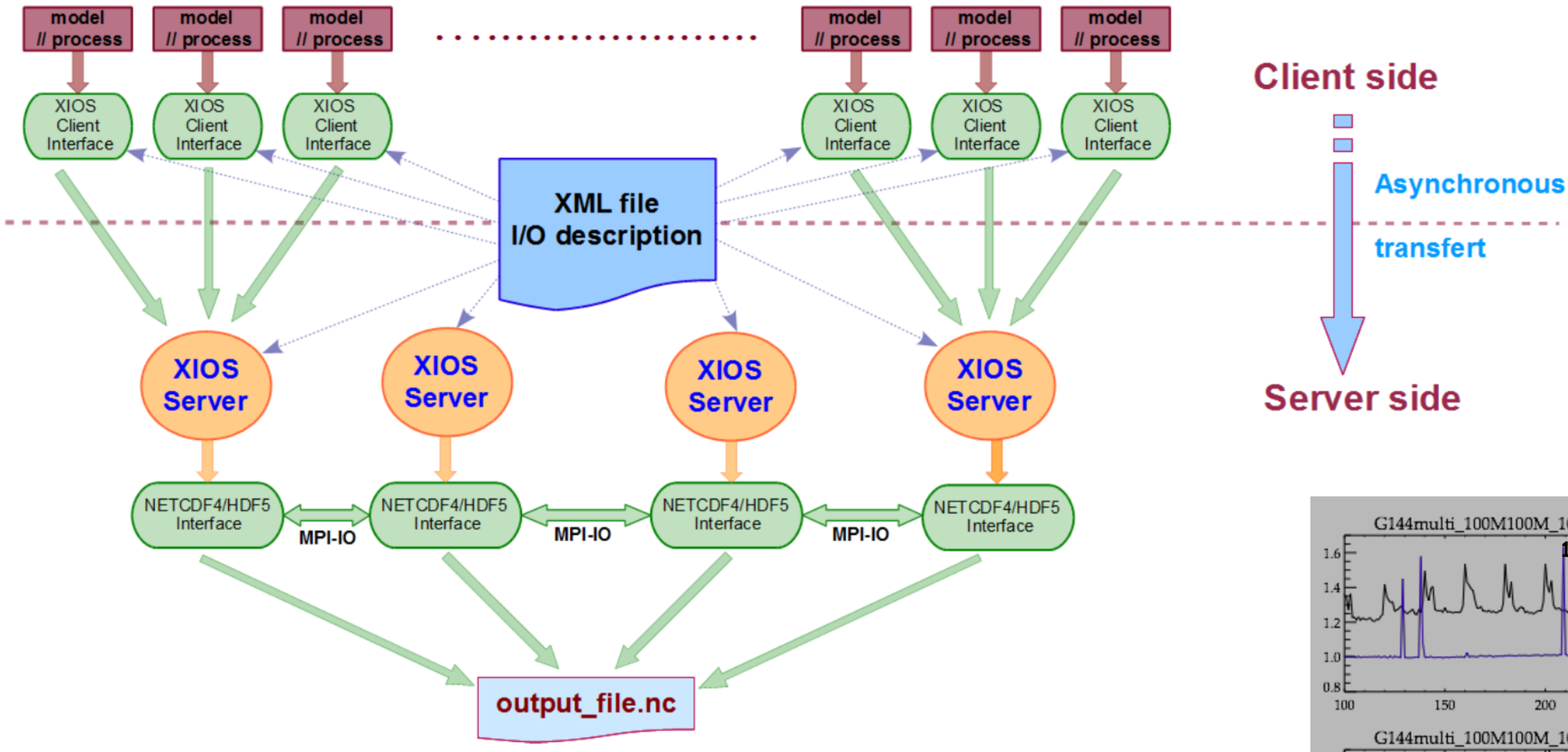


Fast with a global file at the end !!!

Need NetCDF4 library
built with parallel capabilities

MPI => Writing files 4/4 : XIOS

XIOS



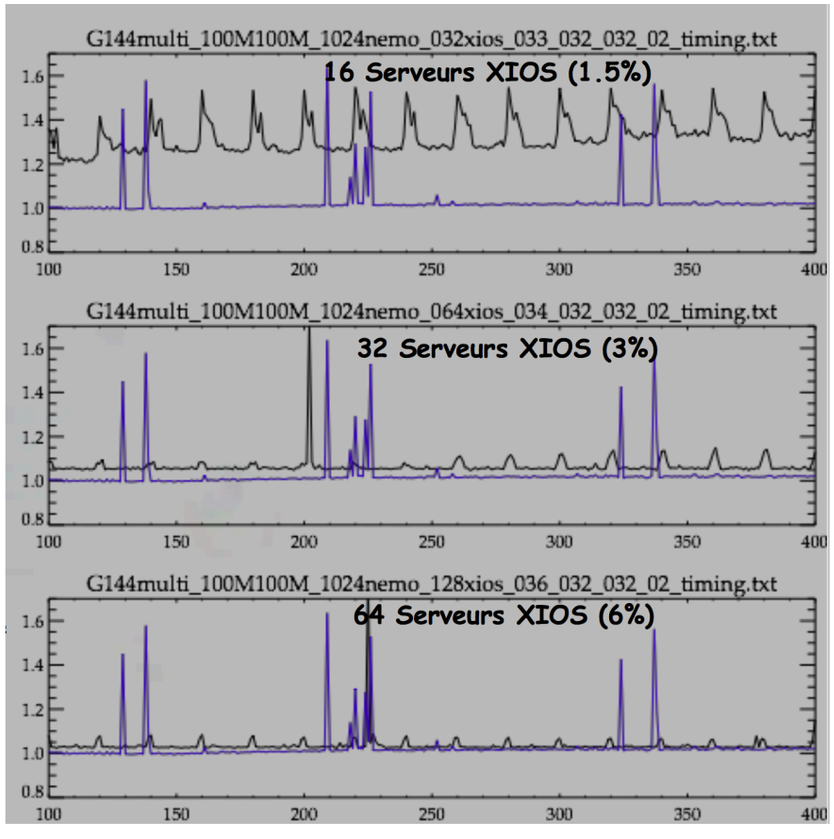
Strategy for outputs

XIOS : external server developed at IPSL

http://forge.ipsl.jussieu.fr/ioserver

Exemple

(S. Masson, from NEMO …)



MPI => Writing files 4/4 : XIOS

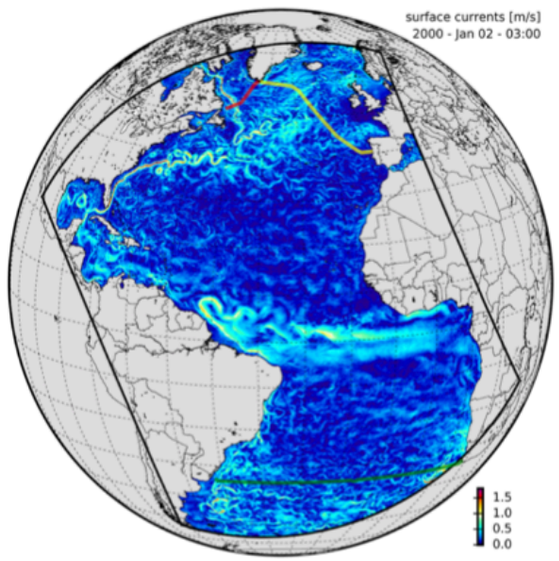
XIOS general

- Originally, a library dedicated to Input/Output management of large climate coupled models (e.g. CMIP simulations for IPCC with NEMO and other code)
- Written and managed at (LSCE-IPSL) by Y. Meurdesoif et al.
- XIOS creates output NetCDF files
- Implemented in other codes (ROMS, MARS3D, CROCO) by non-xios-expert developers despite of a light existing documentation.
- All documentation at http://forge.ipsl.jussieu.fr/ioserver with tutorials, user guide
- Installation of XIOS could be not an easy task to do on a new machine, be sure
  it is already well installed with the right netcdf4 library !
- In the next croco version, XIOS version >=2

Ecriture de fichiers MPI 4/4 : XIOS

XIOS why and when ?

- I/O becomes a bottleneck in parallel computing with using a large amount of processors
  e.g. Atlantic model at **1km** resolution :
  10000 x 14000 x 200 grid points ; using up to ~50000 procs



3km resolution

=> Very difficult or impossible to manage such amount of output datas with classical netcdf library.

- Only an external configuration file is needed to configure the outputs (no need to compile each time)

- create new files
- create new variables from referenced variables
- use time filter (instantaneous, average, cumulate, ...)

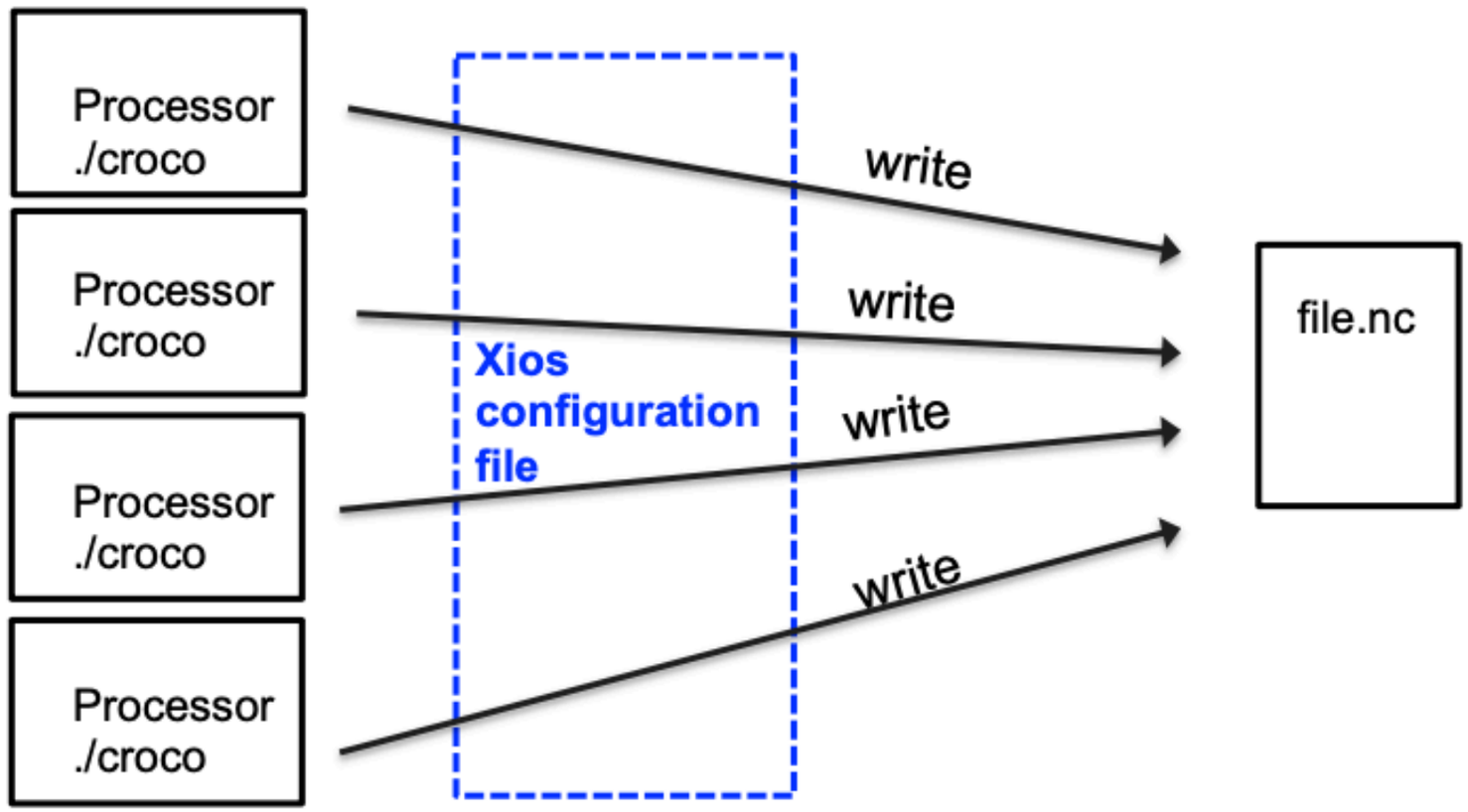
1. Efficiency in production of data on supercomputer parallel file system
2. Flexibility and “simplicity” in management of I/O and data definition

Remark : It is may be not so “ simple ” for beginners because you need to understand how to modify the configuration file written in xml

MPI => Writing files 4/4 : XIOS

XIOS : attached mode

Using xios in **attached mode** :
each croco executable **compute** and **write** (like a classical library)

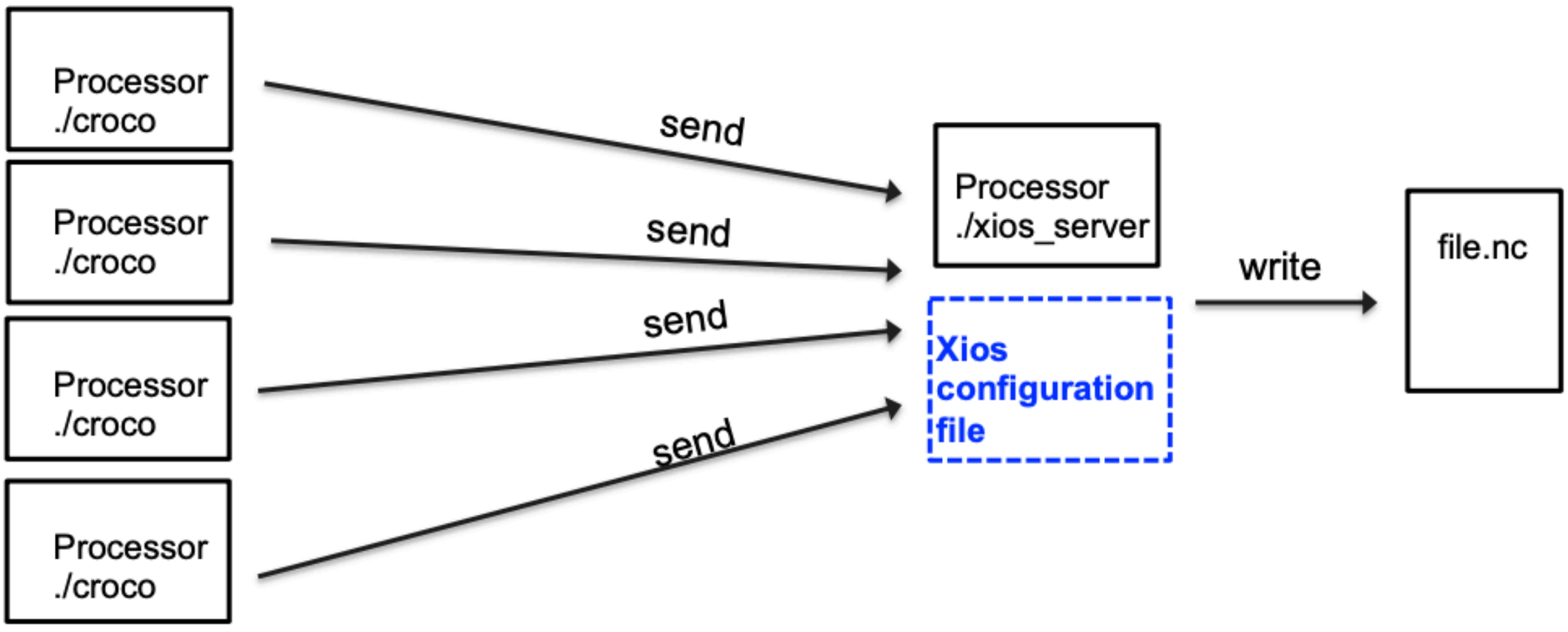


Ergonomy AND efficient parallel writing BUT writing overhead

MPI => Writing files 4/4 : XIOS

XIOS : detached mode (server mode)

each croco executable compute and send field to the server



- croco executables for computing only
- only xios server writes output
- Flexibility AND efficient parallel writing AND (almost) no overhead

MPI => Writing files 4/4 : XIOS

XIOS : in practice

- In cppdefs.h add ccp keys : #define XIOS
- Add the XIOS library path in jobcomp
- Compile once : ./jobcomp
- Edit/modify xios configuration file : iodef.xml
- To run :
  - in attached mode : as usual
  - in detached mode : like a coupled model …

    mpirun -np 10 ./croco -np 2 ./xios.exe

The land only processors case

1. Preprocessing

In croco/MPI_NOLAND :
- read the README
- compile: edit makefile + make
- edit the namelist :
  - name of the grid file
  - number max of cores
- execute : ./mpp_optimize
- visualize :

./mpp_plot.py croco_grd.nc benguela-008x005_033

- re-read le README …

2. Before compiling CROCO

- cppdefs.h : #define MPI_NOLAND
- param.h : insert values for NP_XI, NP_ETA and NPP given by the preprocessing (NPP <= NP_XI x NP_ETA)
- execute as usual (mpirun -np *etc*)

WARNING : grid file as to be called croco_grd.nc (or to be changed in MPI_Setup.F)

```
!'''''''''''''''''''''''''''''''''''''''
!      namproc
!'''''''''''''''''''''''''''''''''''''''
!   jprocx = maximum number of proc
!
&NAMPROC
      jprocx=220
!
!'''''''''''''''''''''''''''''''''''''''
!      namfile  of filename
!'''''''''''''''''''''''''''''''''''''''
! NAMELIST /namfile/ cbathy
! cbathy = name of the  bathy/mask file(nc)
! covdta = Root for the overdata file name .
! Complete name will be {covdta}.{NP_XI}x{NP_ETA}_{NPP}
&NAMFILE
      cbathy='croco_grd.nc'
      covdta = 'benguela'
/
```

```
-bash
(base) sdb-benshila:MPP_PREP rblod$ ./mpp_optimiz
 Number of pts     :        1936
 Number of sea pts :        1411

  optimum choice
  ==============

 --> Number of CPUs : NNODES =           33

  NP_XI =           8  NP_ETA =           5
  Lm =            6  Mm =           9

  number of sea CPUs                33
  number of land CPUs                7
  average overhead          0.69463869463869454
  minimum overhead          0.138461545
  maximum overhead           1.00000000
  nb of overhead p. < 10 %                    0
  nb of overhead p. 10 < nb < 30 %            3
  nb de overhead p  30 < nb < 50 %            5
  number of integration points             4290
  number of additionnal pts                2398
  % sup                                2.26744175

(base) sdb-benshila:MPP_PREP rblod$
```