

# CROCO – training 2024 PSF Barcelonette

## Introduction to CROCO and Parallelization



1. Available Parallelization options in CROCO
2. MPI Concept and techniques
3. MPI Basic setup in Croco
4. Advanced MPI CPP options in CROCO
5. SUMMARY FOR MPI // in CROCO

## 1. MPI Parallelization

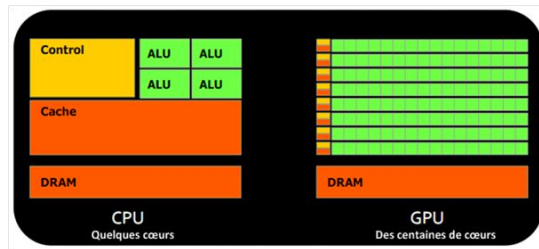
designed for distributed systems, such as clusters of supercomputers where each node has its own memory. Each process in MPI operates in its own memory space, which requires explicit message passing to communicate between them. This makes it ideal for distributed memory environments.

## 2. OPENMP Parallelization

designed for shared-memory systems, typically multiprocessor or multicore computers with shared memory. The threads created by OpenMP share the same memory and can communicate directly without message passing.

# Coming soon...

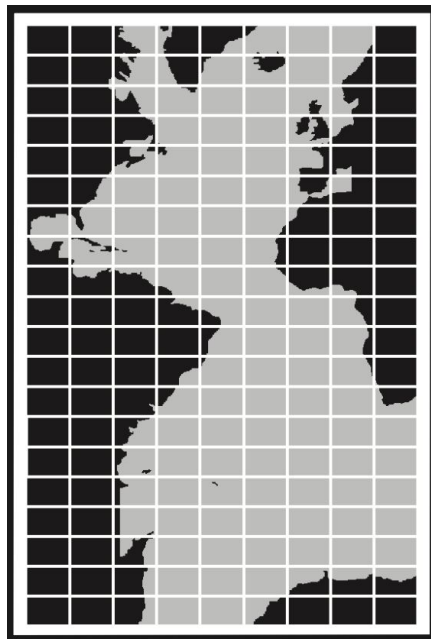
- no hybrid MPI/OpenMP version
- GPU version under development



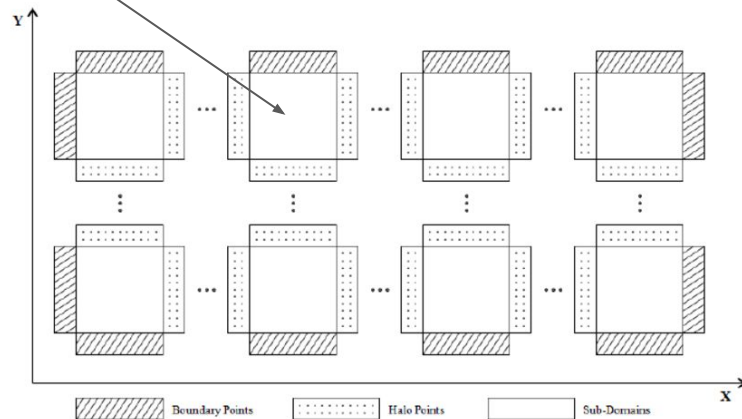
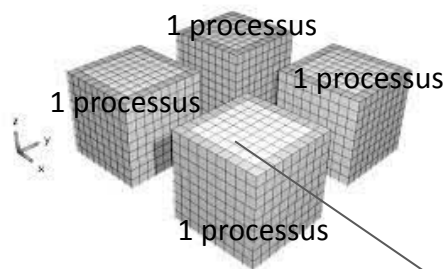
\* MPI // is preferred!

# Concept and techniques : domain decomposition

MPI 9x20 processus



MPI 4 processus

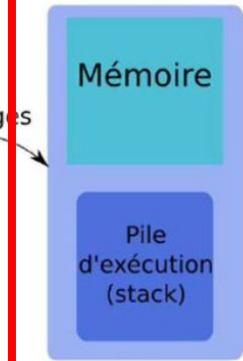


# MPI (Message Passing Interface) : distributed memory

1 calculation core

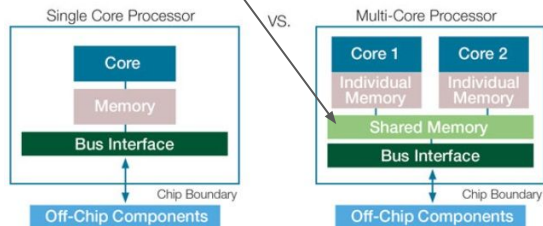


1 calculation core

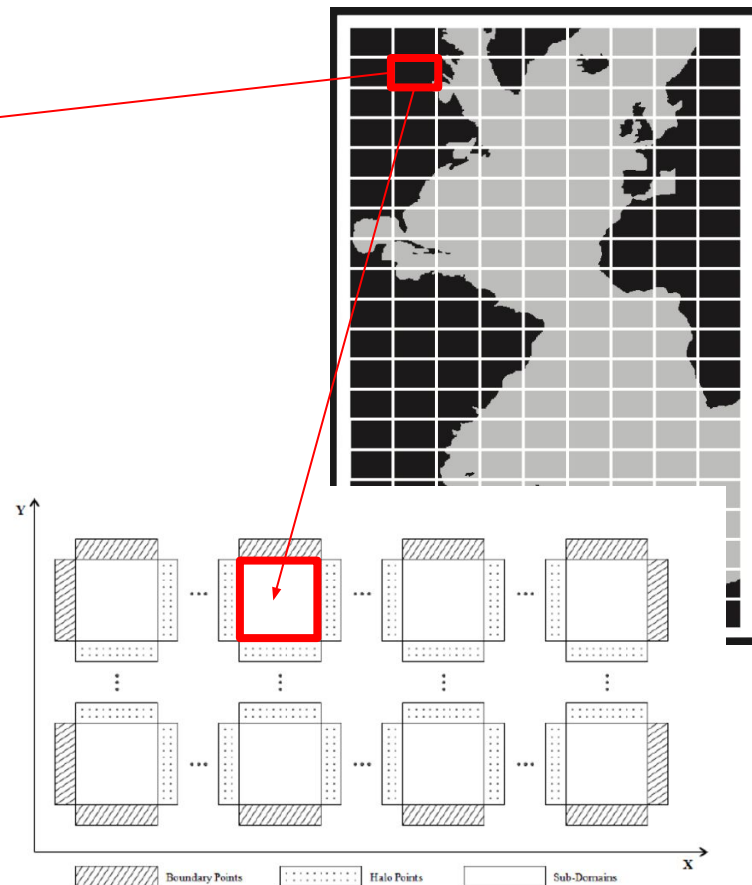


Messages

- => compute cores do not have access to a common memory
- => exchanges via network message
- => in practice, MPI also manages shared memory, but this is transparent to the user.



Comparaison entre les processeurs uni-core et multi-core



# How to configure MPI in CROCO

## STEP1 : edit files

### 1) **param.h**

Specify tiles number in xi and eta directions  
=> NP\_XI, NP\_ETA,  
⚠ maximum of tiles number in ETA direction is preferred

#### Variables in param.h:

- **NP\_XI** : decomposition in XI direction
- **NP\_ETA** : decomposition in ETA direction
- **NNODES** : number of cores (= ``NP\_XI\*NP\_ETA``, except with **MPI\_NOLAND** )
- **NPP = 1**
- **NSUB\_X** and **NSUB\_ETA** , number of sub-tiles (almost always =1)

```
! 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)
```

param.h

### 2) **cppdefs.h** :

activate MPI => #define MPI

## STEP2 : compile

**./jobcomp**

## STEP3 : execute

- **mpirun -n 4 /croco**  
(or mpiexec or other)

Processor Numbers= NNODES

Online documentation:

[https://croco-ocean.gitlabpages.inria.fr/croco\\_doc/model/model.parallel.html](https://croco-ocean.gitlabpages.inria.fr/croco_doc/model/model.parallel.html)

# Example of MPI domains

## Example 1:

8 cores:

- NP\_XI=2, NP\_ETA=4, NNODES=8
- NPP=1, NSUB\_X=1, NSUB\_E=1




# MPI CPP OPTIONS in CROCO

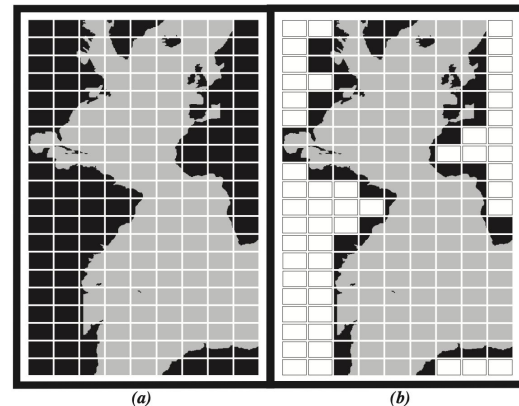
## For writing output files

# AVOID CALCULATION IN LAND AREAS (1)

## 1. Preprocessing

### In directory CROCO/MPI\_NOLAND :

- read README
- compile: edit makefile + make
- edit namelist : grid file name, max number of procs
- execute: /mpp\_optimize
- view : /mpp\_plot.py croco\_grd.nc benguela-008x005\_033
- re-read README ...



```
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'
```

```
(base) sdb-benshila:MPP_PREP rblod$ ./mpp_optimiz

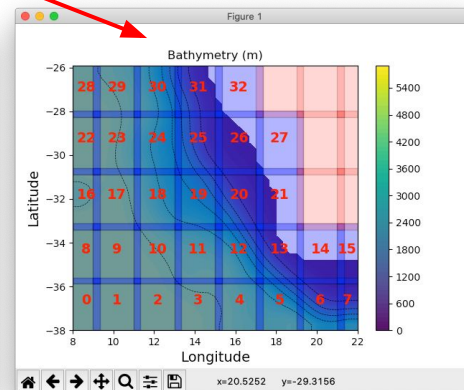
Number of pts : 1936
Number of sea pts : 1411

optimum choice
=====
--> Number of CPUs : NNODES = 33

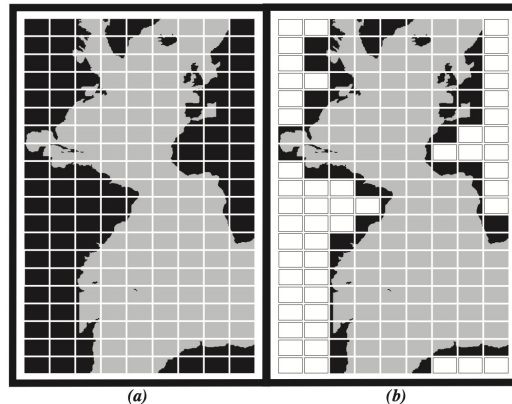
NP_XI = 8 NP_ETA = 5
Lm = 6 Ms = 9

number of sea CPUs 33
number of land CPUs 7
average overhead 0.69463869463869454
minimum overhead 0.138461545
maximum overhead 1.000000000
nb of overhead p. < 10 % 0
nb of overhead p. 10 < nb < 30 % 3
nb of overhead p. 30 < nb < 50 % 5
number of integration points 4298
number of additional pts 2398
% sup 2.26744175

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



# AVOID CALCULATION IN LAND AREAS (2)



## 2. Three files to edit in CROCO

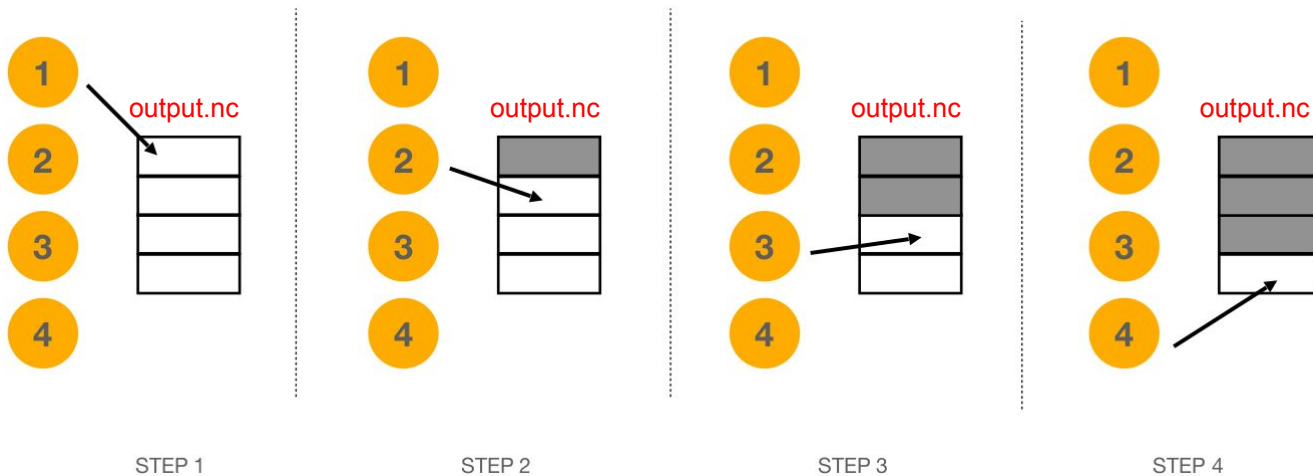
- `cppdefs.h` : CPP OPTION: `#define MPI_NOLAND`
- `param.h`: insert values for NP\_XI, NP\_ETA and NPP given by the preprocessing
- `MPI_Setup.F`: be carefull to the name of grid file  
(NPP ou NNODES  $\leq$  NP\_XI x NP\_ETA )

## 3. Compile and execute

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

# Writing MPI 1/4 files: by default

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

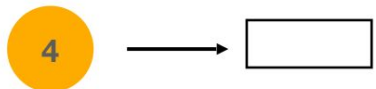
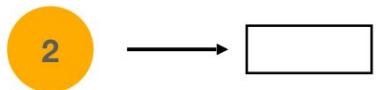
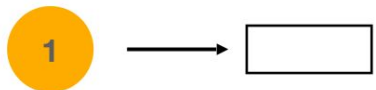


sequential writing, waiting for each proc to finish before the next one writes  
Very inefficient !!!!!!!

## Writing MPI files 2/4: parallel files

`#define PARALLEL_FILES`

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



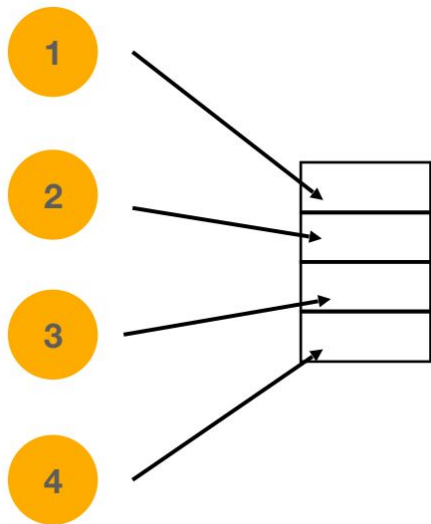
Fast, but many output files

Need to recombine them  
(cf ncjoin utility)

# Writing MPI 3/4 files: parallel writing

```
#define KEY NC4PAR
```

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



Fast with a single output file

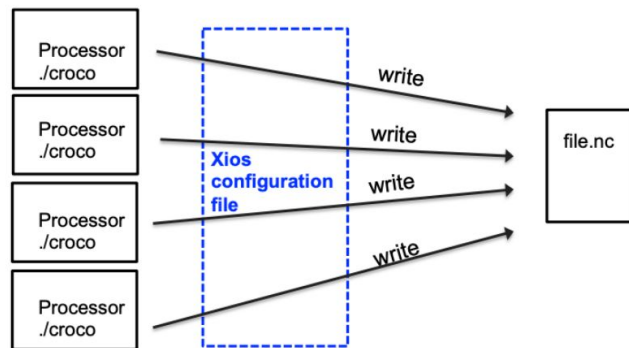
Requires NetCDF4 library  
installed with parallel support

# Writing MPI 4/4 files: XIOS

External server developed at IPSL <http://forge.ipsl.jussieu.fr/ioserver>

## XIOS : attached mode

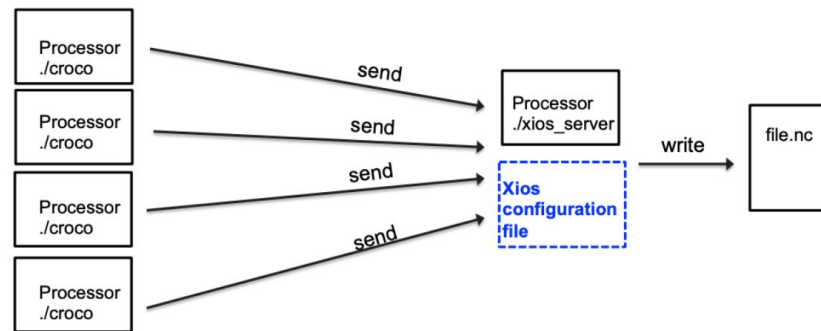
each croco executable compute and **write** (like a classical library)



Ergonomy AND efficient parallel writing BUT writing overhead

## 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

To go further [https://croco-ocean.gitlabpages.inria.fr/croco\\_doc/tutos/tutos.21.xios.html](https://croco-ocean.gitlabpages.inria.fr/croco_doc/tutos/tutos.21.xios.html)

# Writing MPI - SUMMARY -

		Complexity to implement	Disadvantages	Advantages
1	By default	By default	By default	<ul style="list-style-type: none"><li>Simple to implement, nothing to do</li></ul>
2	Parallel Files	<code>#define PARALLEL_FILES</code>	many output files, need to recombine them	<ul style="list-style-type: none"><li>Simple to implement</li></ul>
3	Parallel writing	<code>#define KEY_NC4_PAR</code> library NETCDF 4 Parallel	installation of NETCDF4 can be tricky	<ul style="list-style-type: none"><li>fast with a single output file</li></ul>
4	XIOS attached mode	<code>#define XIOS,</code> XML file	hard to install XIOS and to use it	<ul style="list-style-type: none"><li>very ergonomic and efficient</li><li>useful with a big domain</li></ul>
5	XIOS detached mode	<code>#define XIOS,</code> XML file	hard to install XIOS and to use it	<ul style="list-style-type: none"><li>very ergonomic and efficient</li><li>the best tool with a big domain</li></ul>



- ⇒ Online documentation:  
[https://croco-ocean.gitlabpages.inria.fr/croco\\_doc/model/model.parallel.html](https://croco-ocean.gitlabpages.inria.fr/croco_doc/model/model.parallel.html)
- ⇒ Use MPI on your regional configuration with 4 processus (NP\_ETA=4)