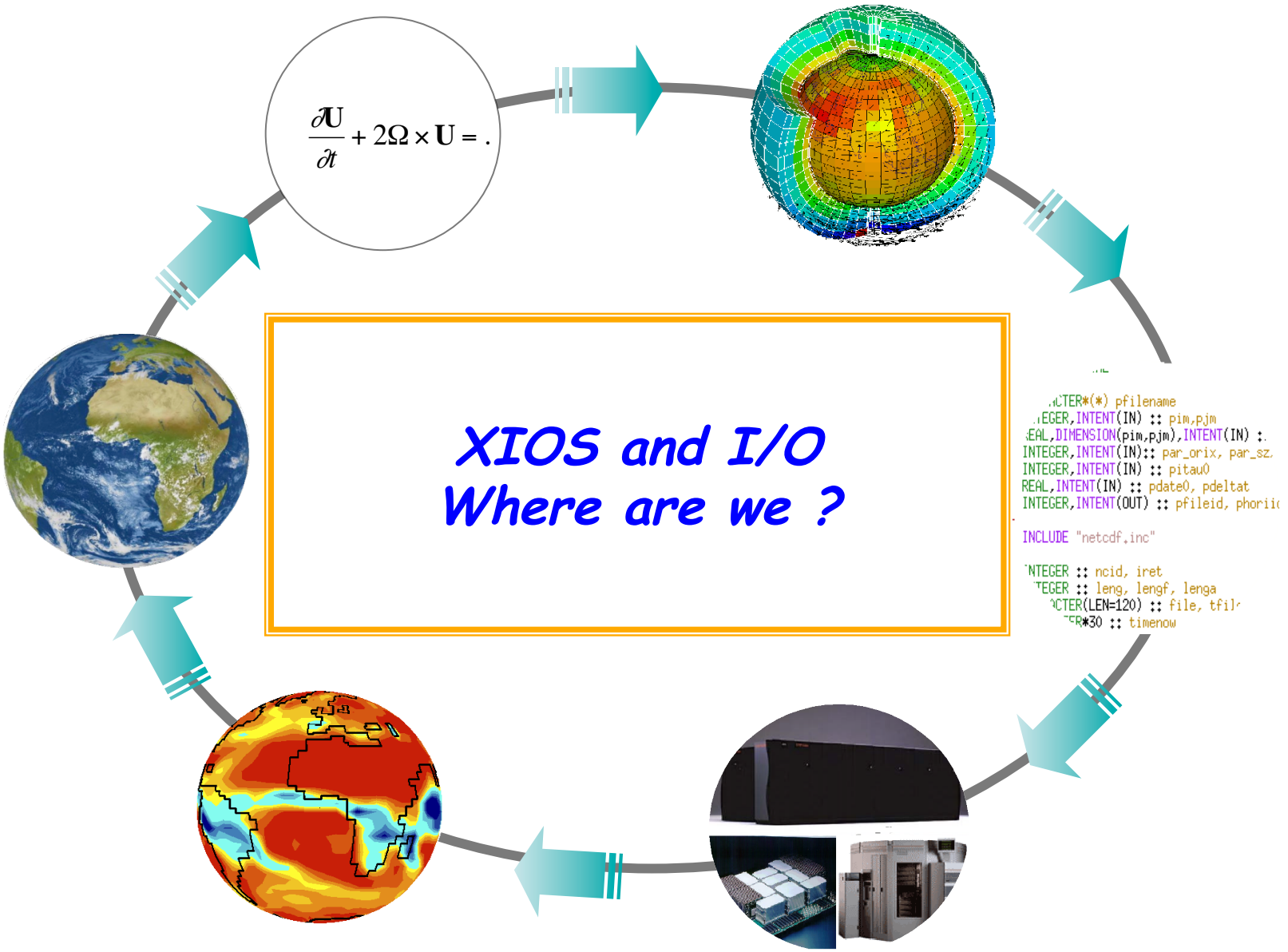
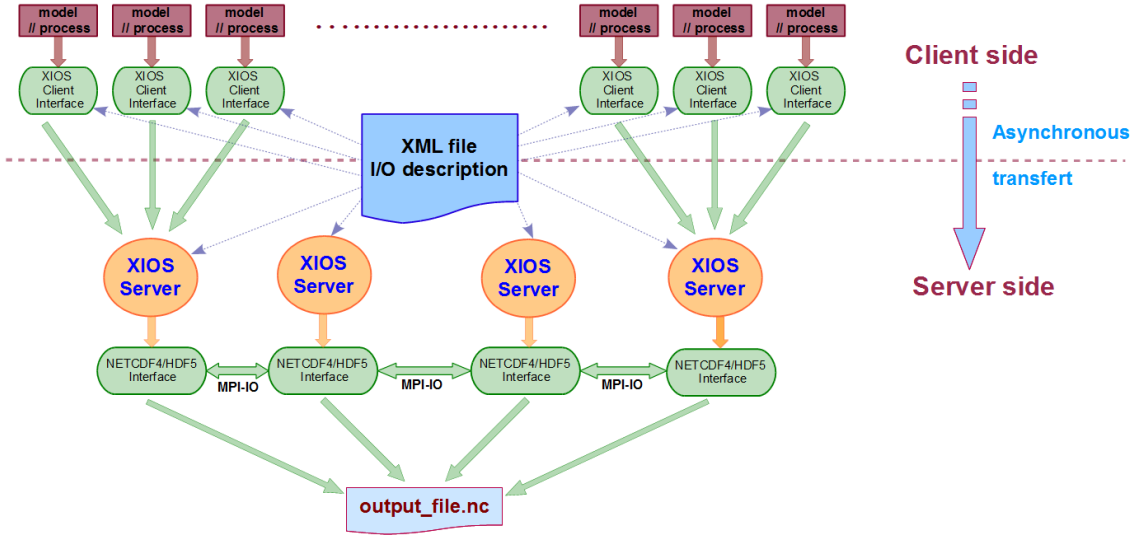
Y. Meurdesoif, M.H. Nguyen, R. Lacroix, A. Caubel, O.Abramkina, Y. Wang, J. Dérouillat



Short reminder : IS-ENES 1 Achievement



❖ Was focused on :

- Flexibility
  - Hierarchical description through an external XML file
- Performance : rules of I/O server
  - Asynchronous dedicated servers : overlapping computation and I/O
  - Rearrange data for better output efficiency
  - Use parallel I/O for better performance

❖ Aggregated Bandwidth ~3-4 GB/s continuously (on Curie)

- ~300 TB/day => 10 PB/month
- Strongly dependent of // file system and NETCDF4/HDF5 parallel I/O performance

IS-ENES2 achievement : what's new ?

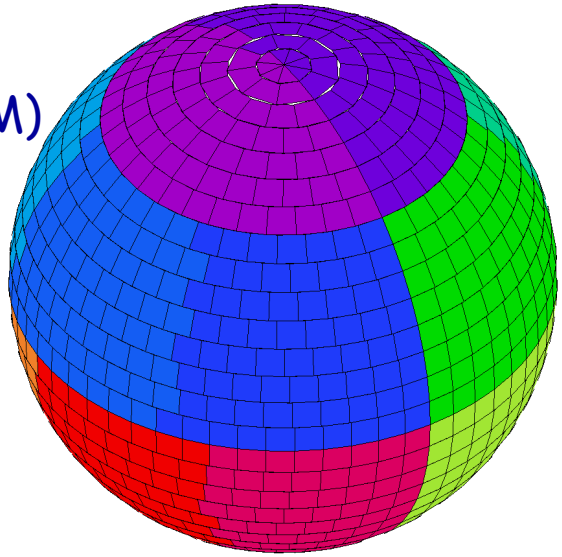
❖ Toward XIOS 2 : more focused on usability and feasibility :

- Support a larger variety of grid
- High resolution output with large number of cores
- Data post-treatment "in situ"
- Dissemination : integration on a larger variety of model
  - Including full earth system models

Supporting new varieties of grids

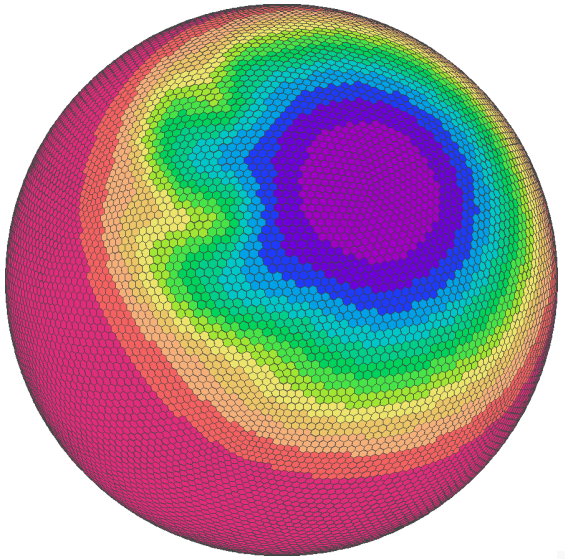
❖ Mesh and data distribution

- Support of reduced gaussian grid (Arpège climat, CNRM)
  - ex: Arpège climat (CNRM-meteofrance)



- Support of unstructured geodesic grids

❖ Next generation of models using XIOS

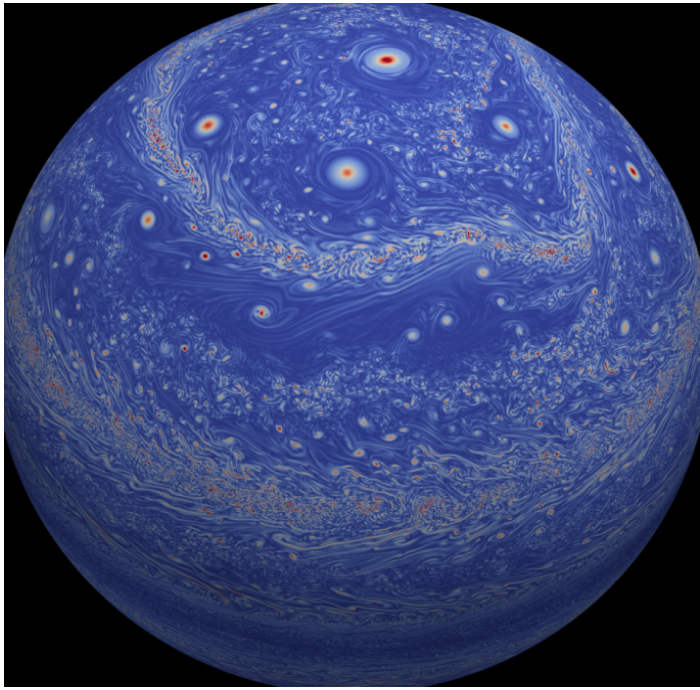


- DYNAMICO (IPSL)
  - Hexagonal geodesic unstructured mesh
- LFRIC (Met Office) -> evaluation
  - Cube sphere, output using U-grid convention

High resolution runs

❖ HR simulations with large number of cores (>10000 cores)

- NEMO global 1/12° (Mercator)
  - Mesh : 4000x3500x75



- NEMO 1/60° North Atlantic (DRAKKAR)
  - GENCI Big Supercomputing Challenges 2015 (J.M Molines)
  - Mesh : 5500x4500x300
  - 13000 cores, 80 I/O servers (5 days output)

- Global 1/8° atmospheric Saturn simulation with DYNAMICO
  - GENCI Big Supercomputing Challenges 2015 (A. Spiga, Y. Meurdesoif)
  - 12000 cores, 1 day output

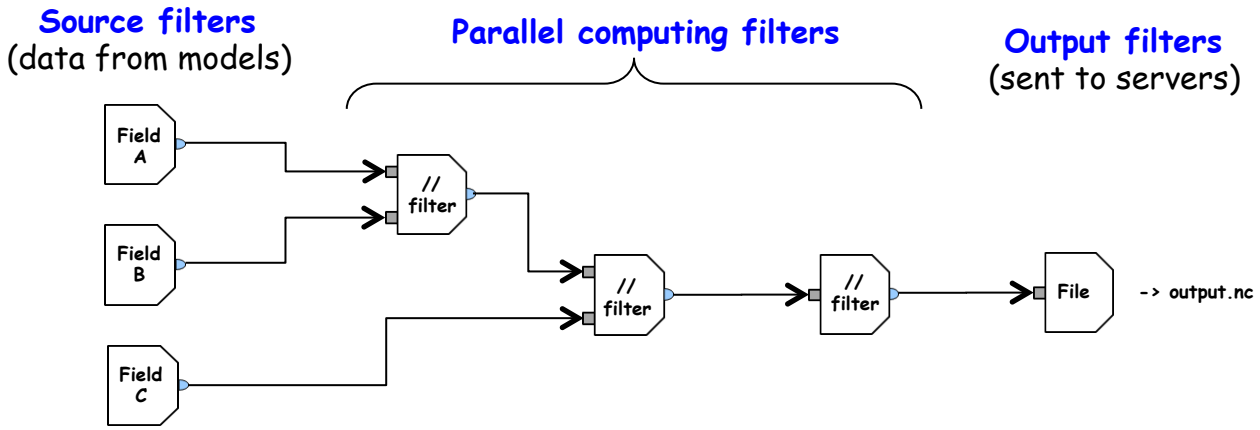
Data post-treatment "in Situ"

❖ Taking advantage of supercomputing resources to perform data treatment in parallel on thousand of computing nodes.

- Done all along the simulation on the allocated computing cores

❖XIOS embeds now an internal workflow/dataflow

- XML file describe a parallel task graph
  - Incoming data are representing data flux, assigned to a timestamp
    - Each flux can be connected to one or more filters
  - Filters are connected to one or more input flux and generate a new flux on output
  - All Filters can be chained to achieve complex treatment
  - All filters are parallel and scalable



Computing filters

3 family of computing filters

- Temporal filters : time integration

```
<field id="temp" unit="K" operation="average"/>
```

  - Ex : instant, average, maximum, minimum, accumulate

- Arithmetic filters
  - Combine different flux from a same timestamp

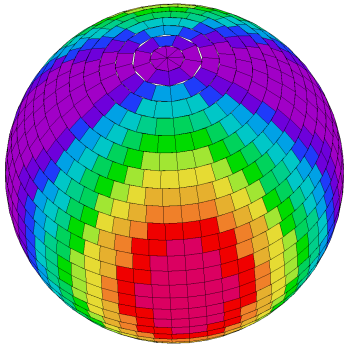
    ex: $C=A+B/A*B$; $D=e\uparrow-C*D/3$

```
<field id="A" />
<field id="B" />
<field id="C"  > (A + B) / (A*B)     </field>
<field id="D"  >  exp(-C*this) / 3  </field>
```

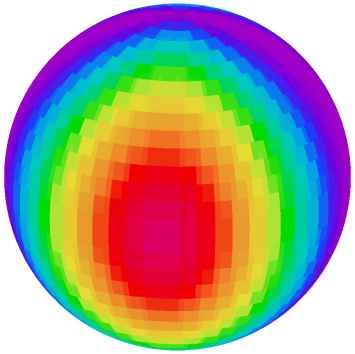
- Spatial filters
  - Geometrical shape of the input flux is modified
    - Defined by a grid transformation from a grid source to target
  - Many complex parallel operations can be performed
    - Data subset extraction (zooming, slicing…)
    - Global or partial spatial reduction (mean, sum, max, min…)
    - Horizontal interpolation
    - Vertical interpolation, pressure levels interpolation
    - Parallel neighbourhood discovery, halo transfer
  - And many more filter in future…

Interpolation

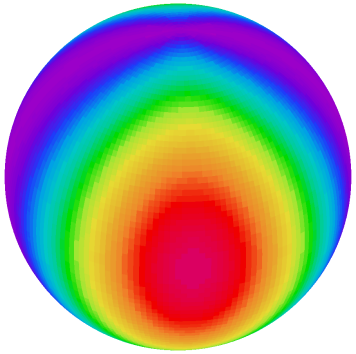
❖ High quality "on the fly", parallel and conservative methods



Native mesh
(gaussian reduced)

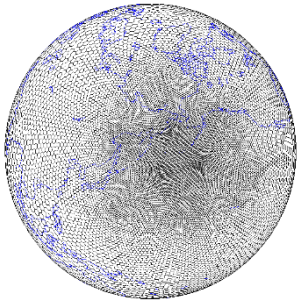


1st order conservative
(regular lon lat 2°)

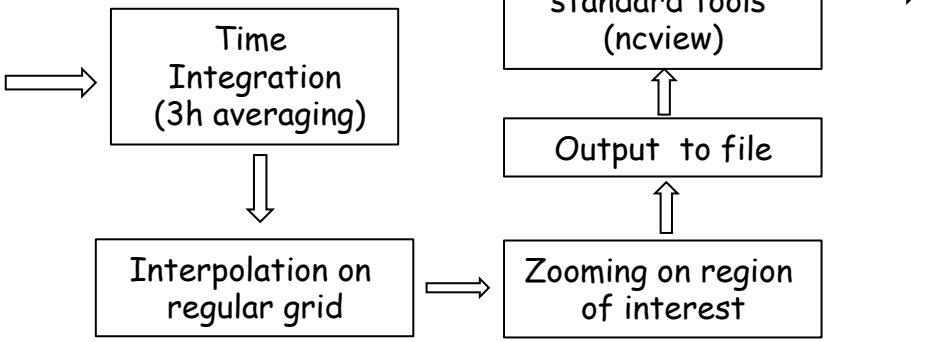


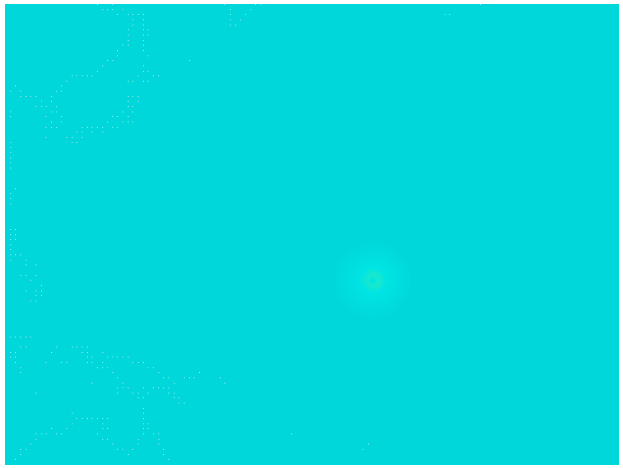
2nd order conservative
(regular lon lat 2°)

Example of simple workflow : DCMIP 2016 cyclone test case with DYNAMICO



Global
unstructured
stretched grid



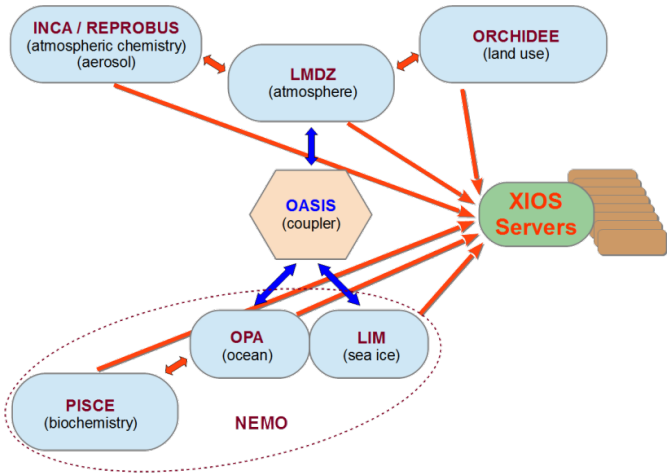


~ 8 km resolution

Dissemination

Implementation in an increasing variety of models

- IPSL : full earth system model
  - NEMO, LMDZ, ORCHIDEE, INCA, DYNAMICO
- Météo France / CNRM : full ESM climate
  - NEMO, Arpege, Surfex, Gelato
- NEMO consortium
- CROCO consortium (costal & regional oceanic)
  - ROMS, MARS3D
- Met Office : MONC
- LGGE : MAR



New projects

- Met Office : Next generation model : LFRIC, on going… (S. Adams)

- Archer eCSE proposal (UK) accepted (G. Lister NCAS-CMS) : 19 PM -> 2017-2018
  - Implementation of XIOS in the Atmospheric Component of the Unified Model
  - Manage ensemble diagnostics trough XIOS

CMIP6 output challenge

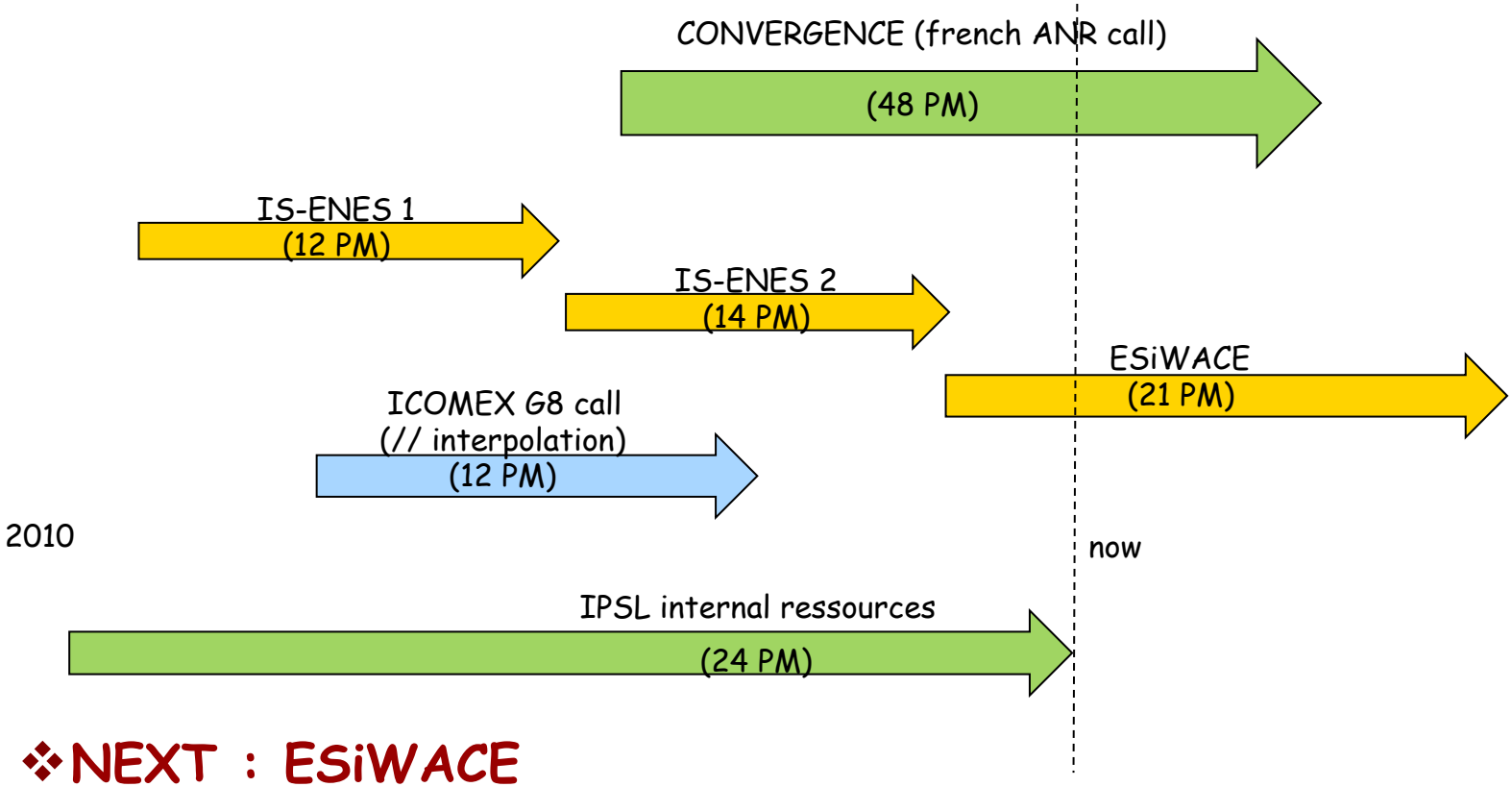
❖ **IPSL and CNRM share a common workflow based on XIOS for CMIP6 output**

- Ideally, produce files as requested by the CMIP6 data request
- Avoid costly post-treatment phases, data are ready to be distributed
- XIOS manage all operation classically devoted to post-treatment phases
  - Vertical interpolation in pressure level
  - Horizontal regriding (if needed)
  - Time series, chunking, compression
  - ……

❖ **Mutualization of CMIP6 workflow is strongly reducing human cost**

Summary and perspectives

- ~ 90 000 code lines in C++, open source (CeCiLL licence)
  - Funded and supported by french and european call



❖ NEXT : ESiWACE

- XIOS suitable for many core architectures (fully multi-threaded)
- Coupling functionalities, possible convergence with OASIS
- GRIB2 output format (ICHEC)