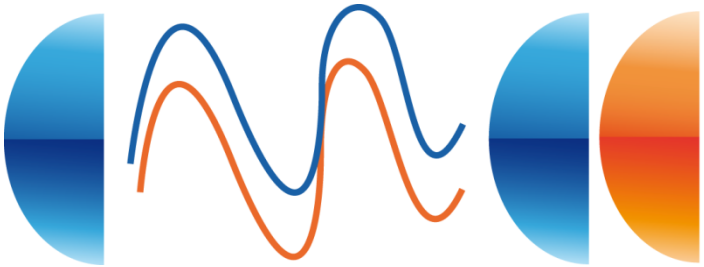

Centro Euro-Mediterraneo
sui Cambiamenti Climatici

Incorporating NEMO into CESM

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1. Overview

- The NEMO ocean model
- Foundamental questions
    - Choice of the sea ice model
    - Choice of the coordinates
    - Coupling interface
- Incorporating NEMO into CESM
- Current status and next steps

2. The NEMO ocean model

NEMO (Nucleus for European Modelling of the Ocean) http://www.nemo-ocean.eu

- Developed by a consortium of EU research centers: **CMCC** (IT), INGV (IT), CNRS (FR), Mercator-Ocean (FR), NERC (UK) & UKMO (UK)
- Solves the primitive equations on an orthogonal curvilinear coordinate system
- Horizontal grid: Arakawa C grid
- Vertical coordinate: z (full/partial steps), s or a mix z-s
- 2° order centered FD scheme; filtered leap-frog
- EOS: Jackett and McDougall (1995)
- Several choices available for the ocean physics
- LIM2/LIM3 sea ice modules; dynamics and thermodynamics of sea ice
- TOP module for passive tracers and interface to marine biogeochemistry
- Implemented on the global domain and on regional domains (i.e. Mediterranean Sea)
- Available global resolutions: 4, 2, 1, 0.5, 0.25 degrees (ORCA tripole grid)
- Parallelization based on domain decomposition through MPI (no OpenMP yet)
- Parallel I/O (optional server/client architecture), each task read/write its own file

3. CESM-NEMO coupling: the sea ice model

Coupling NEMO to the CESM, foundamental questions:

Q1. Which sea ice model do we want to use? LIM vs. CICE

Q2. Which horizontal grid coordinates do we want to use? POP vs. NEMO

Q3. What are the fields that we need to exchange with the coupler? Units & sign convention

(from Q2 & Q3) On which grid do we want to exchange these fields? T vs. U vs. ?

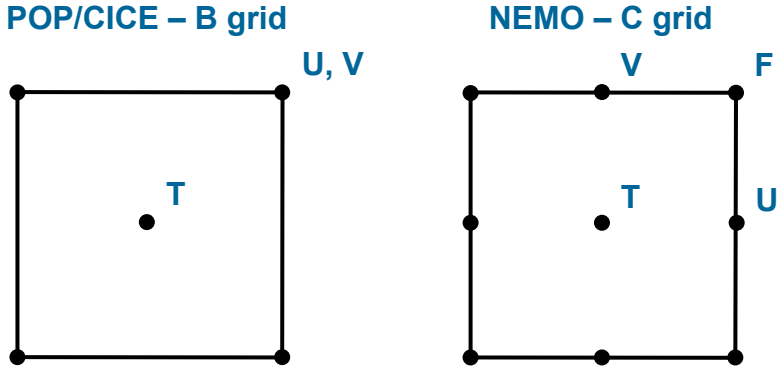
Q1. Which sea ice model do we want to use? LIM vs. CICE

- LIM is not a stand-alone model, it's a module available as an option in the NEMO code (in CESM the sea ice component has to be a model on its own)
- In CESM atmosphere-sea ice fluxes are computed by CICE (LIM does not compute any flux)
- CICE (partly!) supports the NEMO tripole grid

Q1. Which sea ice model can we use?
A1. CICE

3. CESM-NEMO coupling: the horizontal grid

Q2. Which horizontal grid coordinates do we want to use? POP vs. NEMO



- POP coordinates → Rebuild NEMO grids & metrics, bathymetry, initial/boundary conditions, ...
- NEMO coordinates → Mapping (weights) & domain files + CICE files adaptation

Q2. Which horizontal grid coordinates do we want to use?
A2. NEMO grid

- **On what grid do we want to exchange these fields?** T vs. U vs. ?

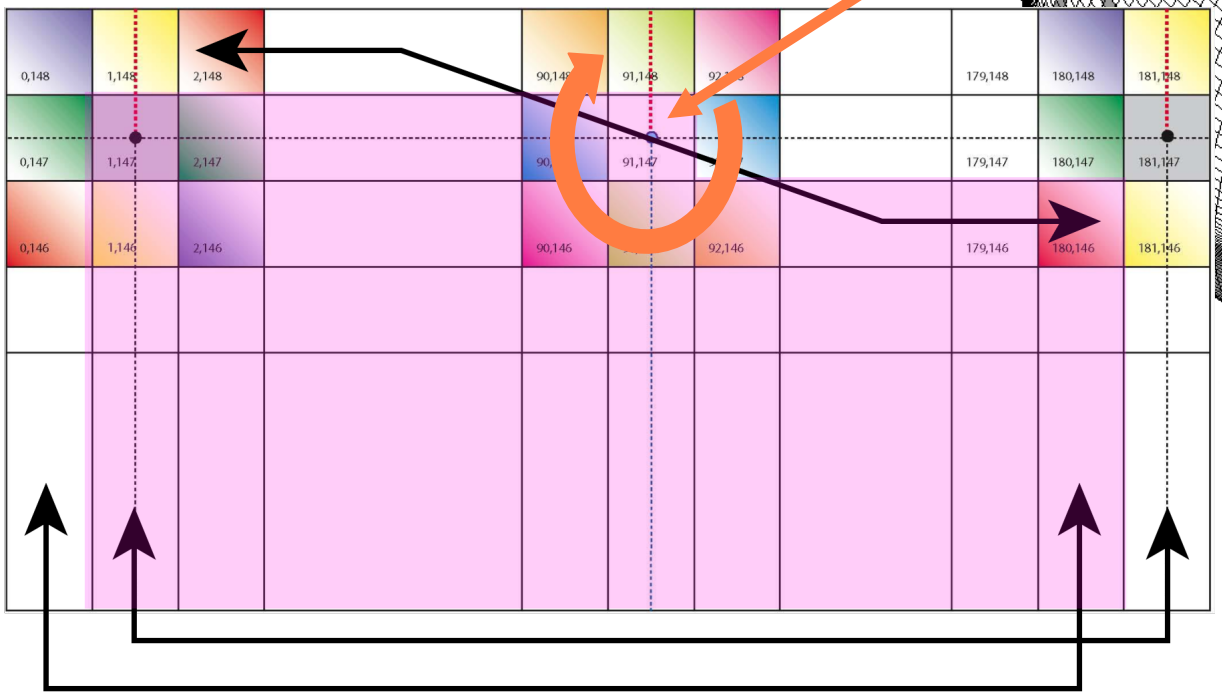
CPL allows only 1 grid/mask/area per model → all the fields have to be exchanged on the same grid

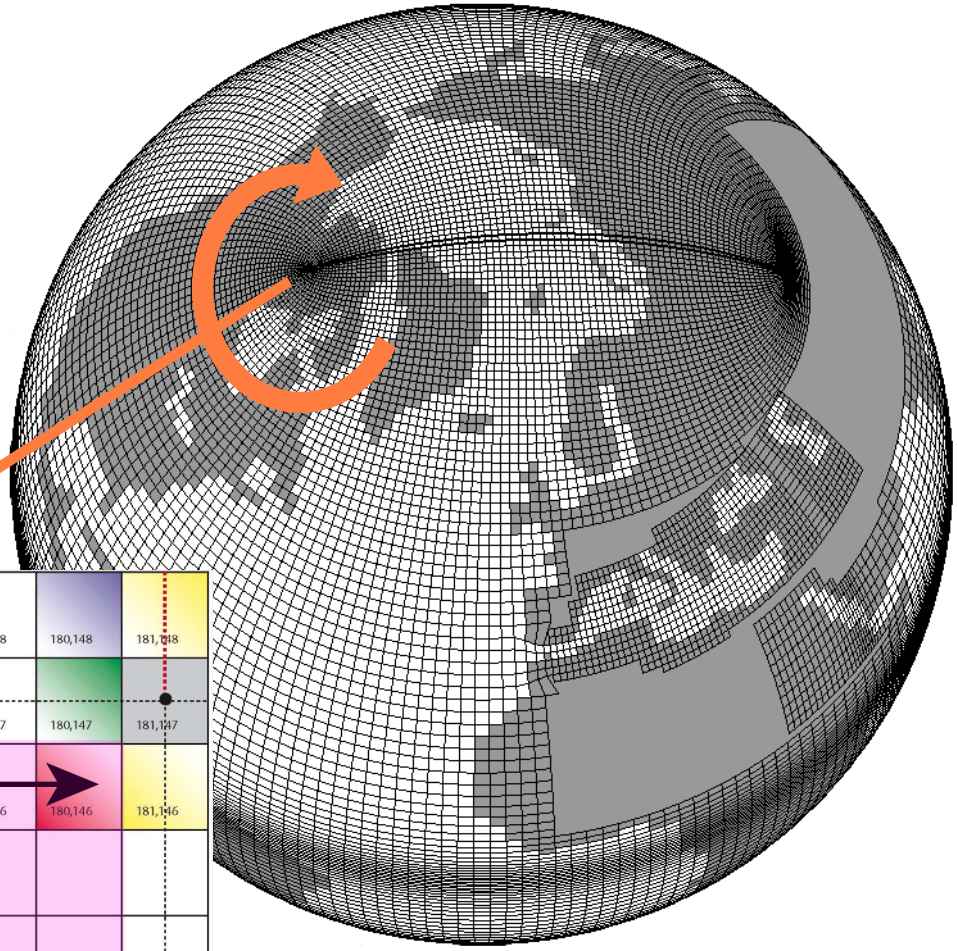
Q. On which grid do we want to exchange these fields?
A. Central T points

3. CESM-NEMO coupling: the horizontal grid

NEMO tripole grid (ORCA2: ~2 deg)

- Added to the CESM supported grids: tn2v1
- All NEMO fields contain the global domain halo
- T-fold type: poles on central T points (POP tripole grid is U-fold type
- Land point used to increase the resolution over marginal/internal seas





3. CESM-NEMO coupling: the coupling interface

Q3. What are the fields that we need to exchange with the coupler?

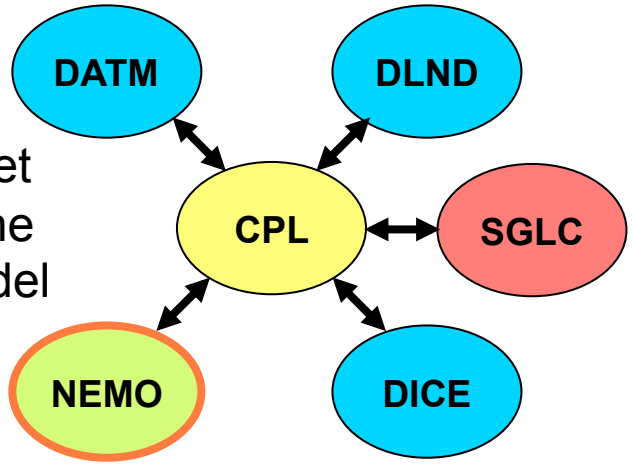
Unit system: POP → cgs NEMO → mks

Sign convention: POP → positive downward NEMO → positive downward

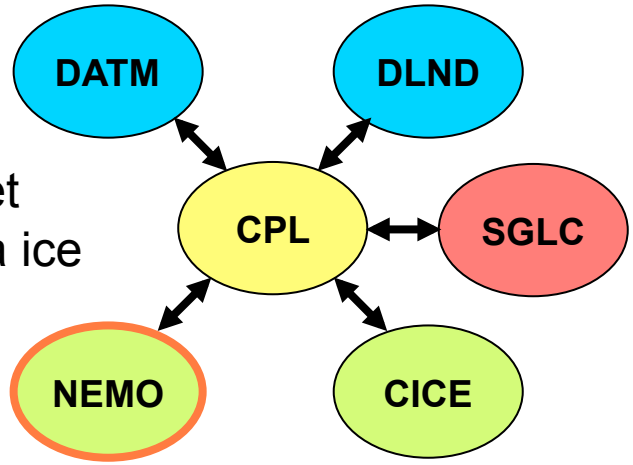
OCN → CPL									
Name	**Meaning**	**Units**		**Positive**		**Grid**		**Target mod**	**Comment**
		OCN	**CPL**	**OCN**	**CPL**	**Source**	**Target**		
UVEL	u horiz. velocity	cm/s	m/s	-	-	U > T+rot	Atm, T+rot > U	Atm+Ice	
VVEL	v horiz. velocity	cm/s	m/s	-	-	U > T+rot	Atm, T+rot > U	Atm+Ice	
SST	Sea Surf. Temperature	degC	K	-	-	T	Atm, T	Atm+Ice	
SSS	Sea Surf. Salinity	g/g	ppt	-	-	T	T	Ice	
GRADPX	x horiz. surf. gradient	cm/cm	m/m	-	-	U > T+rot	T+rot > U	Ice	
GRADPY	y horiz. surf. gradient	cm/cm	m/m	-	-	U > T+rot	T+rot > U	Ice	
QFLUX	frazil sea ice freezing - melting heat flux	W/m^2	W/m^2	down	down	T	T	Ice	Need to add the computation in NEMO
CO2FLUX	CO2 flux	$kg/m^2/s$	$kg/m^2/s$	down	down	T	Atm	Atm	if ecosys mod is active

4. Incorporating NEMO into CESM

C_ compset
Stand-alone
ocean model



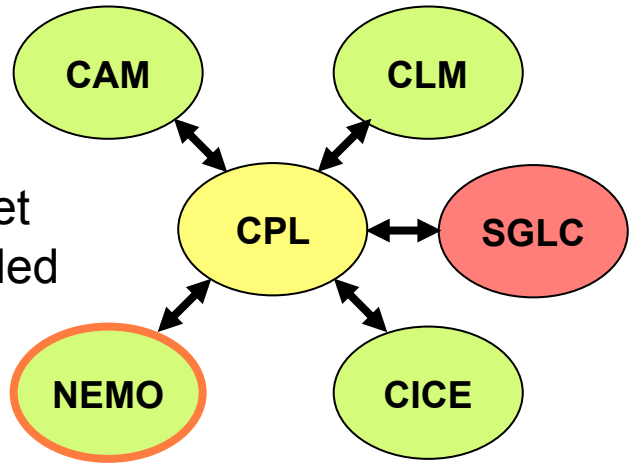
G_ compset
Ocean+sea ice



The target:

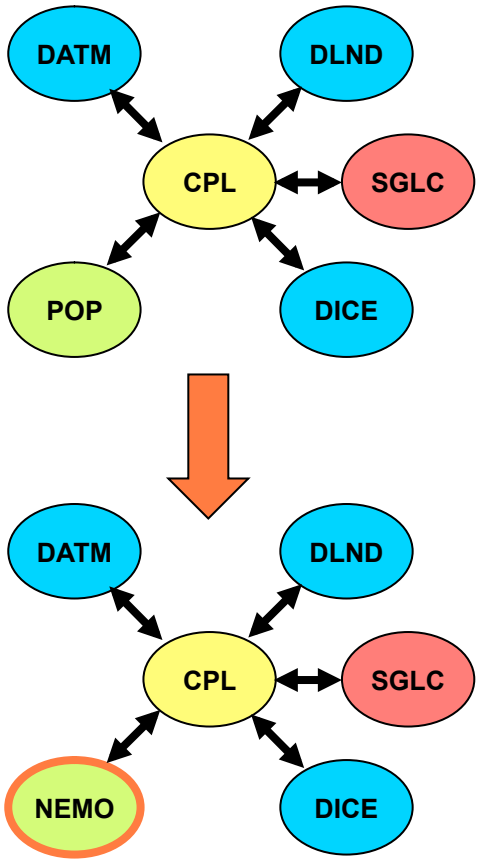
full integration of the NEMO ocean model into the CESM infrastructure

B_ compset
Fully coupled



4. Incorporating NEMO into CESM: Step 1

New C_ compset: C_NORMAL_YEAR_NEMO

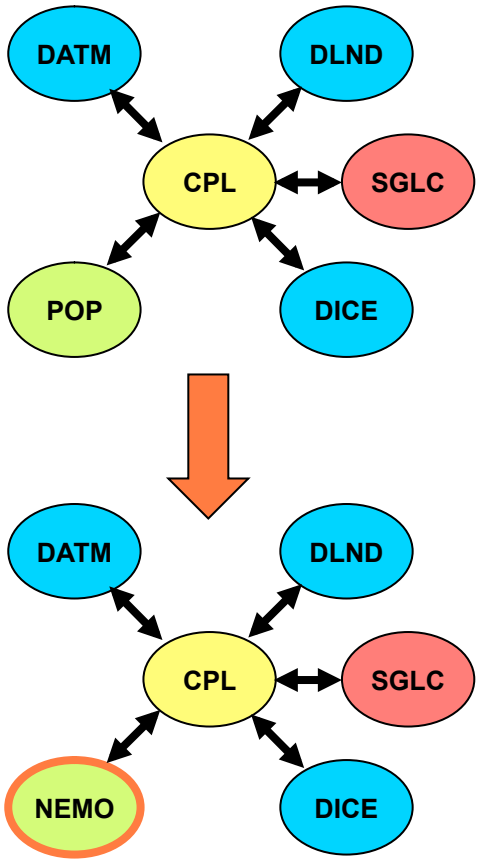


- Generation of domain and mapping files for the NEMO tripole grid (ORCA2) -> gen_maps / gen_domain tools (thanks to M. Vertenstein & M. Levy)
  - Remove global domain halo
  - Mask out overlapping grid points
  - Mask out lakes
- Generation of mapping files for the runoff (thanks to B. Kauffman)
- Addition of the NEMO tripole grid to the list of CESM supported grid
  - ORCA2 (~ 2°): tn2v1 (short name: n21)

```
$CCSMROOT/scripts/ccsm_utils/Case.template/config_grid.xml
...
<horiz_grid GLOB_GRID="tn2v1"  nx="180"  ny="148"  />
...
<horiz_grid GRID="T62_tn2v1" SHORTNAME="T62_n21”
...
```

4. Incorporating NEMO into CESM: Step 1

New C_ compset: C_NORMAL_YEAR_NEMO



- Creation of a new C_ compset (stand-alone ocean model) which uses NEMO as the ocean component

```
$CCSMROOT/scripts/ccsm_utils/Case.template/config_compsets.xml
...
<compset GEN_COMPSET_MATCH="_NEMO" COMP_OCN="nemo"
     VALID_GRID_MATCH="f09|f19|T62" />
...
<compset NAME="C_NORMAL_YEAR_NEMO" SHORTNAME="CNEMO"
     DESC="Active NEMO ocean model with COREv2 normal year forcing"
     DATM_MODE="CORE2_NYF" />
...
```

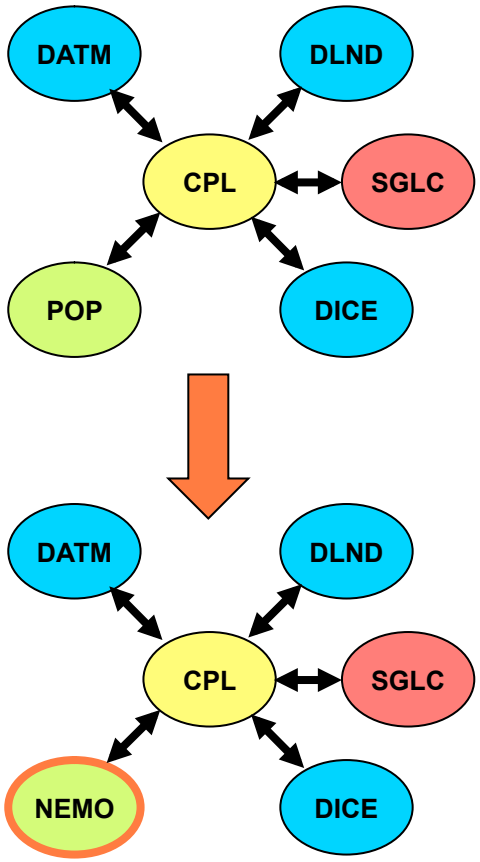
```
$CCSMROOT/scripts/ccsm_utils/Case.template/config_definition.xml
...
<entry id="COMP_OCN" valid_values="pop2,docn,xocn,socn,camdom,nemo"
...
```

```
$CCSMROOT/scripts/ccsm_utils/Case.template/ConfigCase.pm
...
@comps  = qw(cam datm clm dlnd cice dice pop2 nemo docn cism);
...
```

```
$CCSMROOT/scripts/create_newcase
...
my @comps  = qw( ... nemo ... )
my %templates = (... nemo => "models/ocn/nemo/bld/nemo.cpl7.template",
...
```

4. Incorporating NEMO into CESM: Step 1

New C_ compset: C_NORMAL_YEAR_NEMO



- Import NEMO source code into the CESM source tree

```
$CCSMROOT/models/ocn/nemo
```

- Set up NEMO build in the CESM infrastructure
  - mkDepend modifications for NEMO dependencies

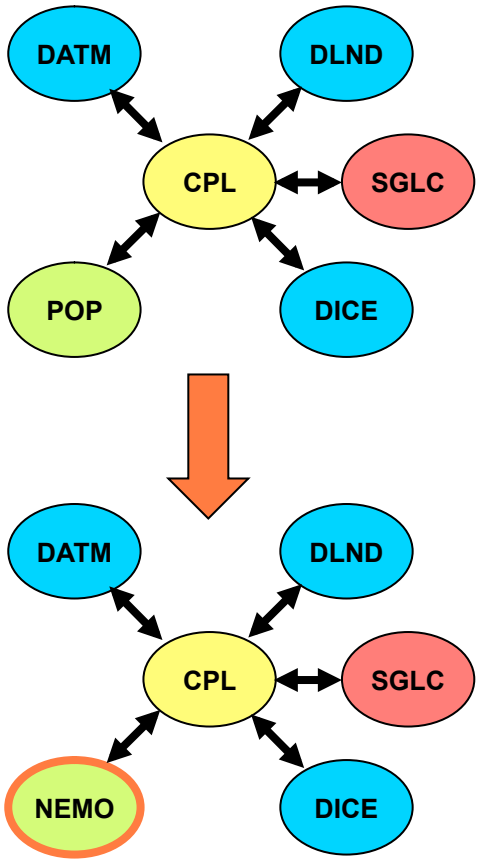
```
$CCSMROOT/scripts/ccsm_utils/Machines/Macros.bluefire
...
FFLAGS = ...
FFLAGS_OPT = ...
...
```

- Creation of the model template nemo.cpl7.template
  - Still preliminary (no build-namelist, no ocn_in)

```
$CCSMROOT/models/ocn/nemo/bld/nemo.cpl7.template
```

4. Incorporating NEMO into CESM: Step 1

New C_ compset: C_NORMAL_YEAR_NEMO



- Implementation of a new driver interface for NEMO (CPL-NEMO communication and syncronization) based on the MCT

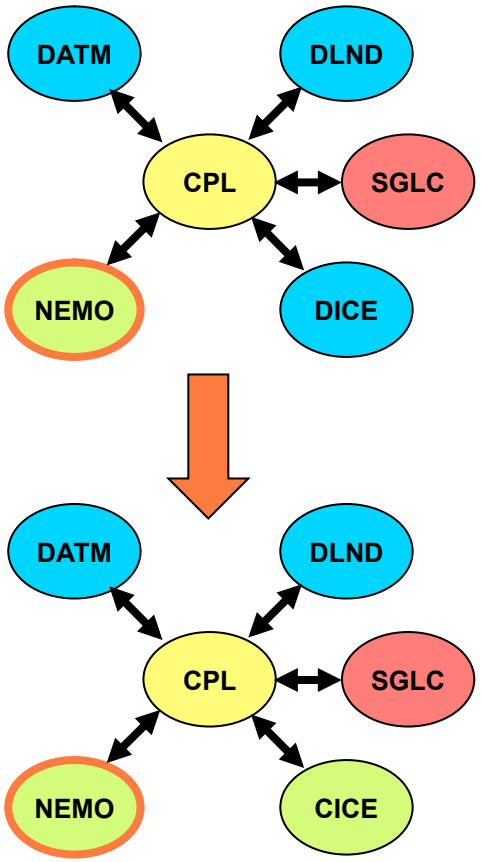
```
$CCSMROOT/models/ocn/nemo/drivers/cpl_mct/ocn_comp_mct.F90
```

- Modifications to NEMO for the coupling with CESM (CPP macros)
- Set up the running environment
  - postrun / archiving (integration with the NEMO I/O)

```
$CCSMROOT/scripts/ccsm_utils/Tools/st_archive.sh
```

4. Incorporating NEMO into CESM: Step 2

New G_ compset: G_NORMAL_YEAR_NEMO



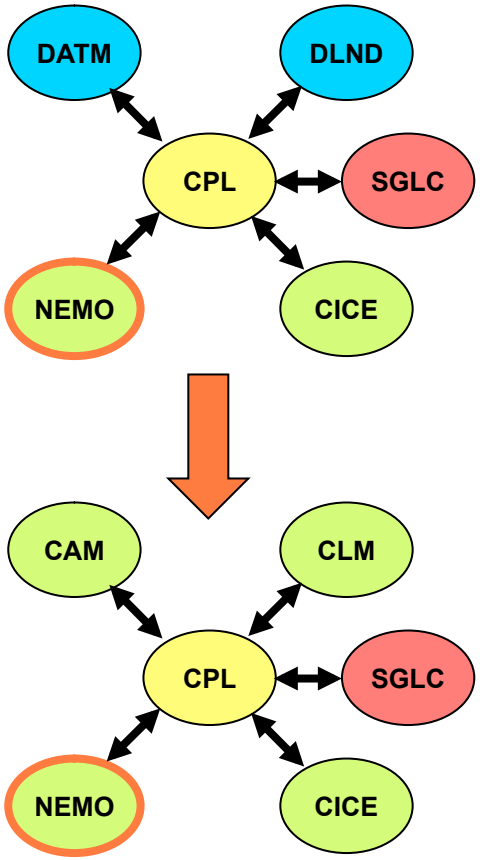
- Generation of NEMO tripole grid coordinates, metrics and mask files for CICE
- Creation of a new G_ compset (active ocean & sea ice) which uses NEMO as the ocean component and where CICE runs on the NEMO tripole grid

```
$CCSMROOT/scripts/ccsm_utils/Case.template/config_compsets.xml
...
<compset NAME="G_NORMAL_YEAR_NEMO" SHORTNAME="GNEMO"
         DESC="Coupled ocean (NEMO) ice with COREv2 normal year forcing"
         DATM_MODE="CORE2_NYF"   DATM_PRESAERO="clim_2000"
/>
...
```

- Completion of the coupling interface: implementation of the computation of the QFLUX (freezing melting potential) in NEMO
- Modify CICE to run on the NEMO tripole grid
  - Grid coordinates, metrics and masks read from file
  - Handling of the overlapping grid point on the T-fold tripole grid

4. Incorporating NEMO into CESM: Step 3

New B_ compset: B_2000_NEMO



- Creation of a new B_ compset (fully coupled model) which uses NEMO as the ocean component and the NEMO tripole grid for ocn/ice

```
$CCSMROOT/scripts/ccsm_utils/Case.template/config_compsets.xml
...
<compset NAME="B_2000_NEMO" SHORTNAME="BNEMO"
         DESC="All active components (NEMO ocean model), present day"
/>
...
```

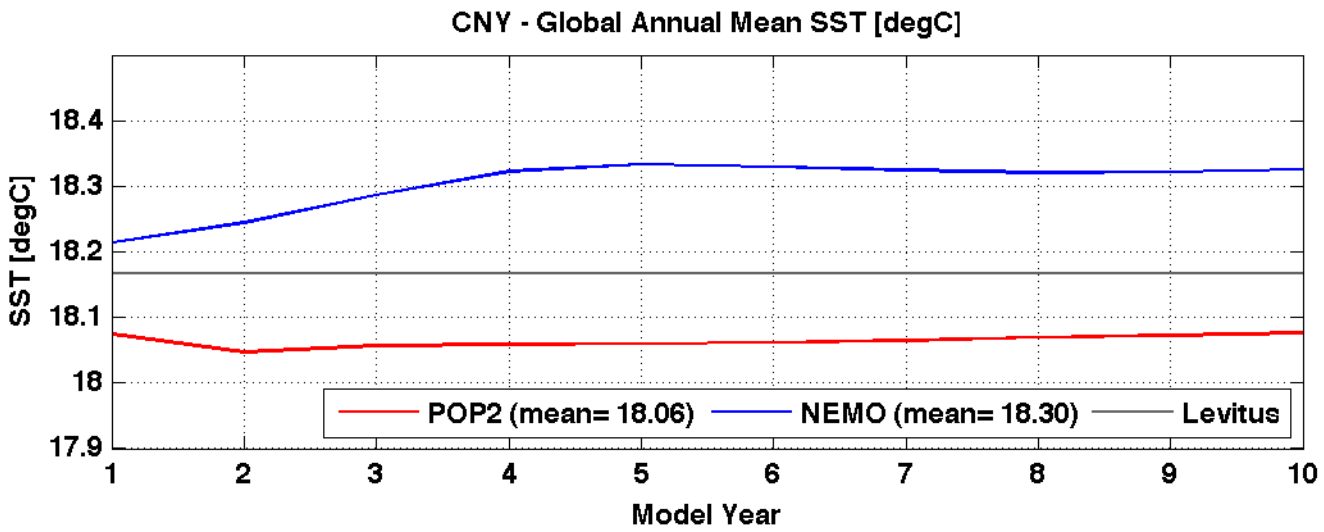
5. Current status and next steps

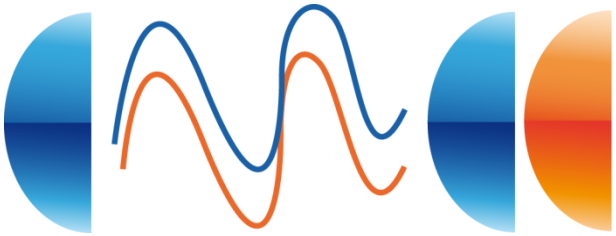
- ☑ Steps 1-3 completed
- ☑ Bit-for-bit reproducibility with different processors layout
- ☑ Exact restart
- ☐ Model validation: stand alone & fully coupled run (biases, conservation, trends, …)
- ☐ Performance analysis
- ☐ Multi-instance capability
- ☐ Strenghten the CESM-NEMO integration (nemo.cpl7.template, postrun)
- ☐ Standardized NEMO post-processing
- ☐ …

6. Preliminary results

C_NORMAL_YEAR_NEMO compset

- 10 years run
- Horizontal resolution: T62_tn2v1 (tn2v1 -> ORCA2 grid, 180x148, ~2 deg)
- Vertical resolution: 31 vertical levels
- Initial conditions: T & S from Levitus; ocean at rest
- Forcings: COREv2
- Comparison with C_NORMAL_YEAR (POP2), T62_tx1v1





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The best is yet to come!

Stay tuned: piergiuseppe.fogli@cmcc.it

Thanks