Centro Euro-Mediterraneo sui Cambiamenti Climatici

Preliminary results of the CESM-NEMO coupling

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1. Motivation

- Define a coherent development roadmap for the next generation models
- Flexible structure to expand toward Earth System Models
- Better sustainability (improved numerical methods, new computer architectures, processing tools)
- Leveraging partnerships and collaborations
- Large community to share experiences and developments

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)

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

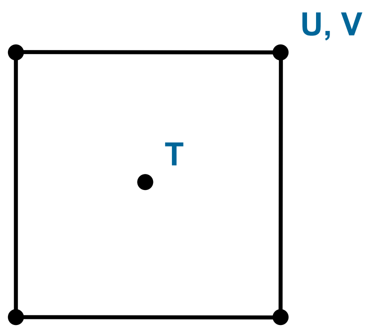
- LIM is not a stand-alone model, it's a module available as an option in the NEMO code (in CESM the sea ice component has to be a model on its own)
- In CESM atmosphere-sea ice fluxes are computed by CICE (LIM does not compute any flux)
- CICE (partly!) supports the NEMO tripole grid

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

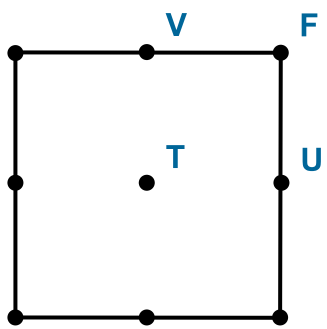
3. CESM-NEMO coupling: the horizontal grid

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

POP/CICE – B grid



NEMO – C grid



- 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. ?

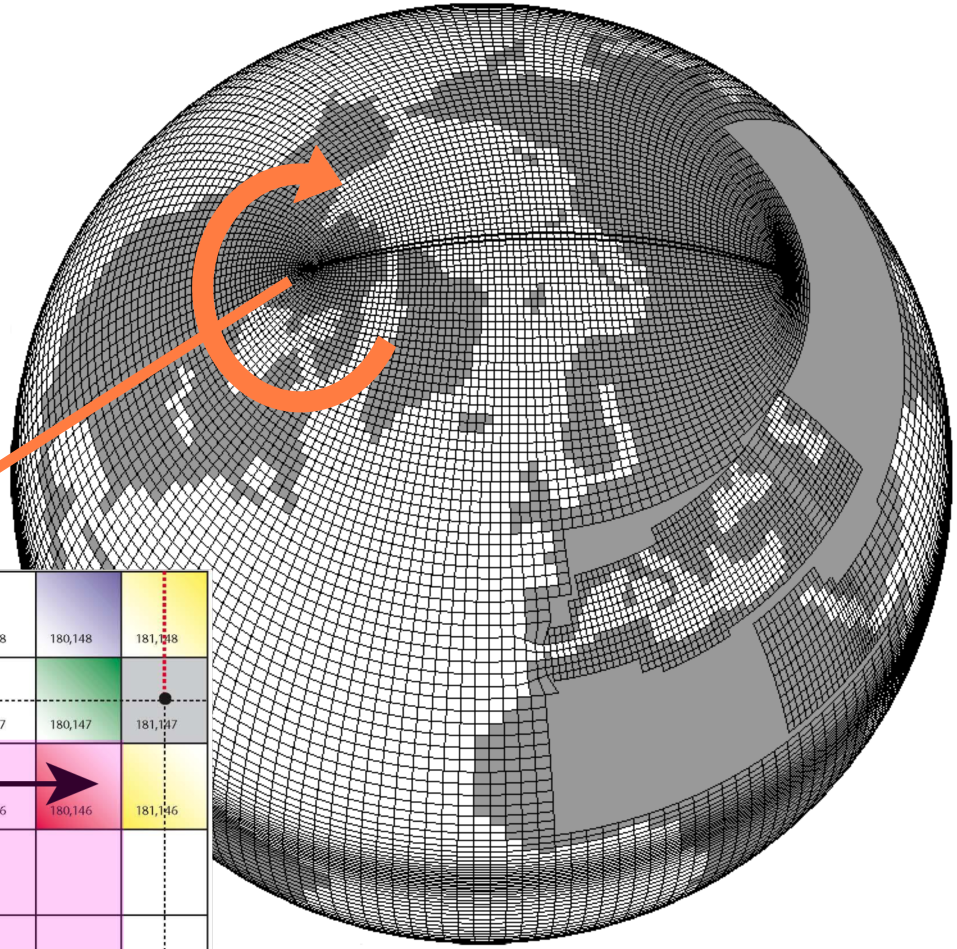
CPL allows only 1 grid/mask/area per model → all the fields have to be exchanged on the same grid

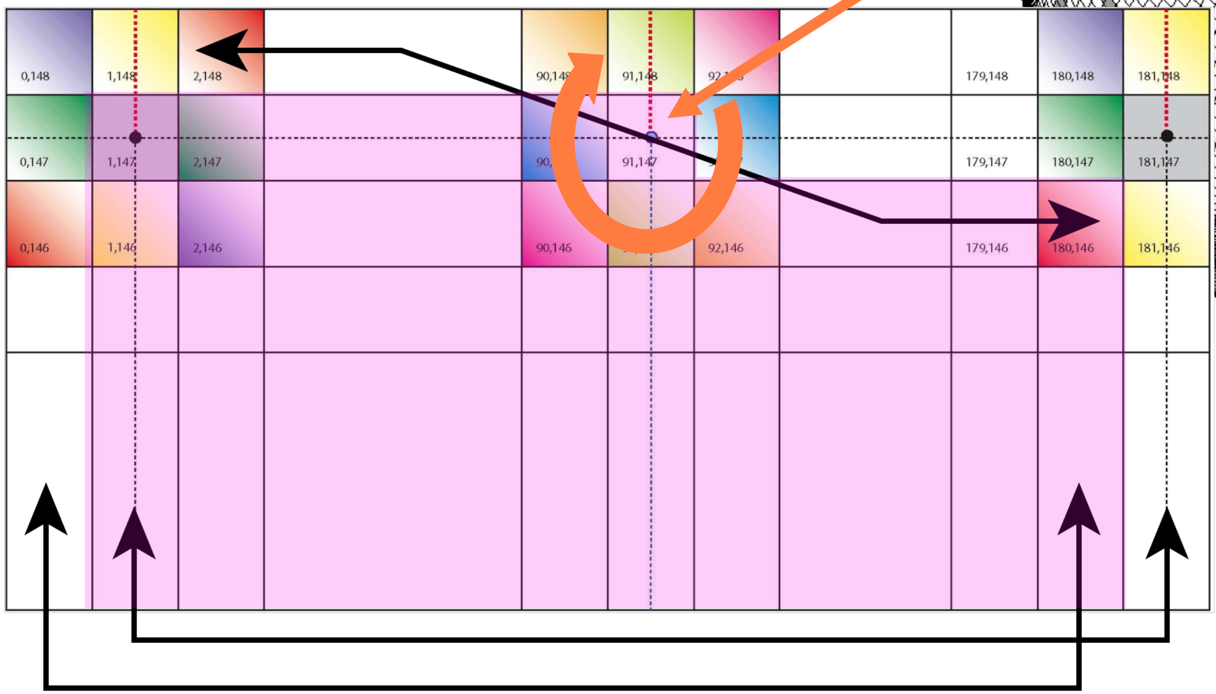
Q. On which grid do we want to exchange these fields?
A. Central T points

3. CESM-NEMO coupling: the horizontal grid

NEMO tripole grid (ORCA2: ~2 deg)

- Added to the CESM supported grids: tn2v1
- T-fold type: poles on central T points (need to complete support in CICE)
- 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

3. CESM-NEMO coupling: the coupling interface

CPL → OCN						
Name	**Meaning**	**Units***	**Positive**	**Grid**	**Source mod**	**Comment**
taux	Zonal wind/ice-ocean stress	N/m^2 (Pa)[×]	-	T > U+rot	Atm+Ice	
tauy	Meridional wind/ice-ocean stress	N/m^2 (Pa)[×]	-	T > U+rot	Atm+Ice	
snow	Water flux due to snow	$kg/m^2/s$	down	T	Atm	
rain	Water flux due to rain	$kg/m^2/s$	down	T	Atm	
evap	Evaporation flux	$kg/m^2/s$	down	T	Atm	
meltw	Water flux due to snow/sea ice freezing/melting[=]	$kg/m^2/s$	down	T	Sea ice	
salt	Salt flux from melting sea ice	$kg(s)/m^2/s$	down	T	Sea ice	
swnet	Net short-wave heat flux	W/m^2	down	T	Atm+Ice[&]	
sen	Sensible heat flux	W/m^2	down	T	Atm	
lwup	Longwave radiation (up)	W/m^2	down	T	Atm	
lwdn	Longwave radiation (down)	W/m^2	down	T	Atm	
melth	Heat flux due to snow/sea ice melting	W/m^2	down	T	Sea ice	
ifrac	Ice fraction	0-1	-	T	Sea ice	
roff	River runoff flux	$kg/m^2/s$	down	T	Land	
ioff	Ice runoff flux due to Land-Model	$kg/m^2/s$	down	T	Land	
pslv	Sea-level pressure	Pa	-	T	Atm	
duu10n	10m wind speed squared	m^2/s^2	-	T	Atm	
co2	Bottom atm level CO_2	ppmv[+]	-	T	Atm	If ecosystem mod is active

4. Current status

☑ Integration of NEMO in CESM

- NEMO tripole grid added ; domain and mapping files created
- New compsets created (C_NORMAL_YEAR_NEMO, G_NORMAL_YEAR_NEMO, B_2000_NEMO)
- NEMO source code integrated in CESM
- NEMO build in the CESM infrastructure
- CICE adaptation (to be completed!)
- Set up of the running environment

☑ Technical tests

- Bit-for-bit reproducibility
- Exact restart

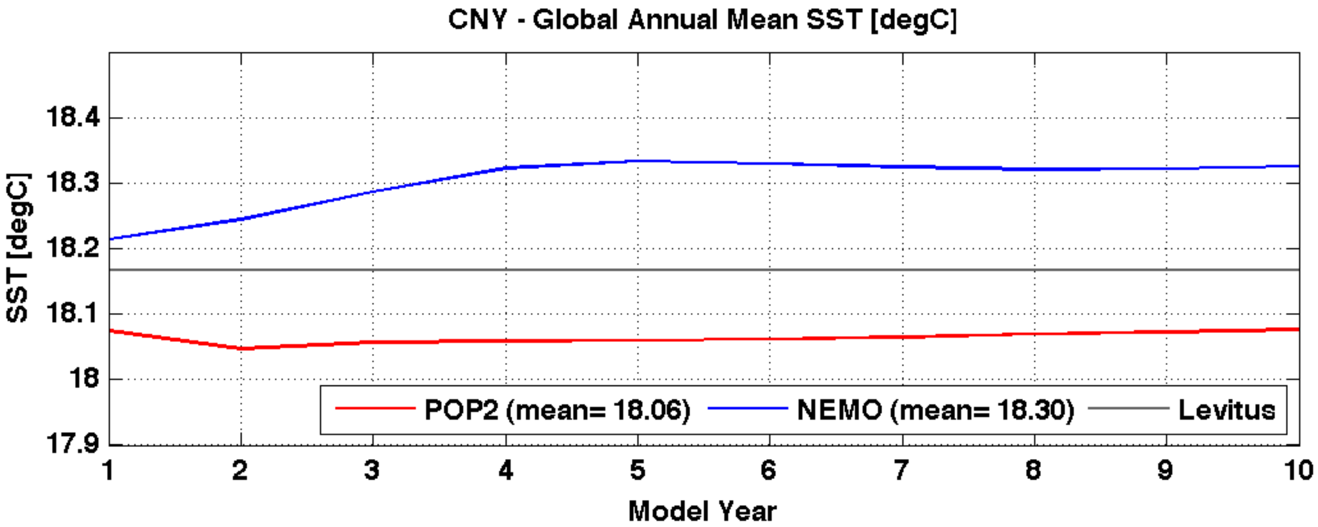
☐ Exact restart for CICE on the NEMO tripole grid

☐ Model validation

5. Preliminary results

C_NORMAL_YEAR_NEMO compset

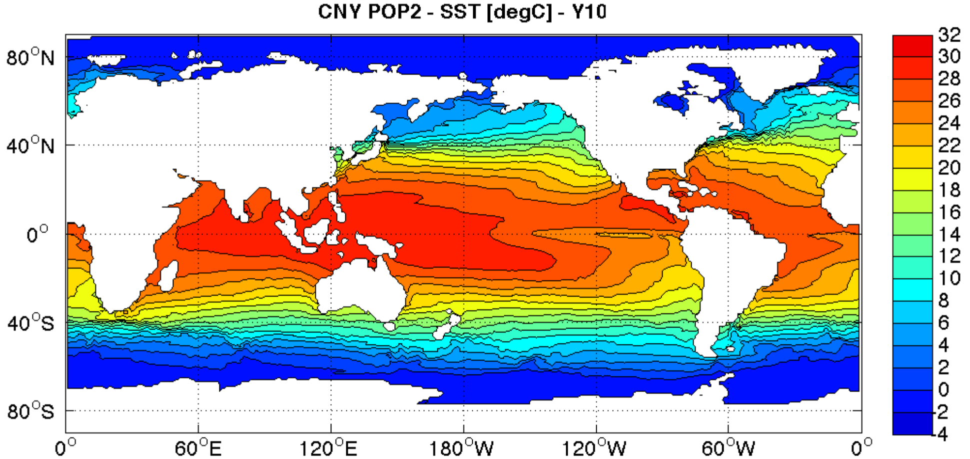
- 10 years run
- Horizontal resolution: T62_tn2v1 (tn2v1 -> ORCA2 grid, 180x148, ~2 deg)
- Vertical resolution: 31 vertical levels
- Initial conditions: T & S from Levitus; ocean at rest
- Forcings: COREv2
- Comparison with C_NORMAL_YEAR (POP2), T62_tx1v1



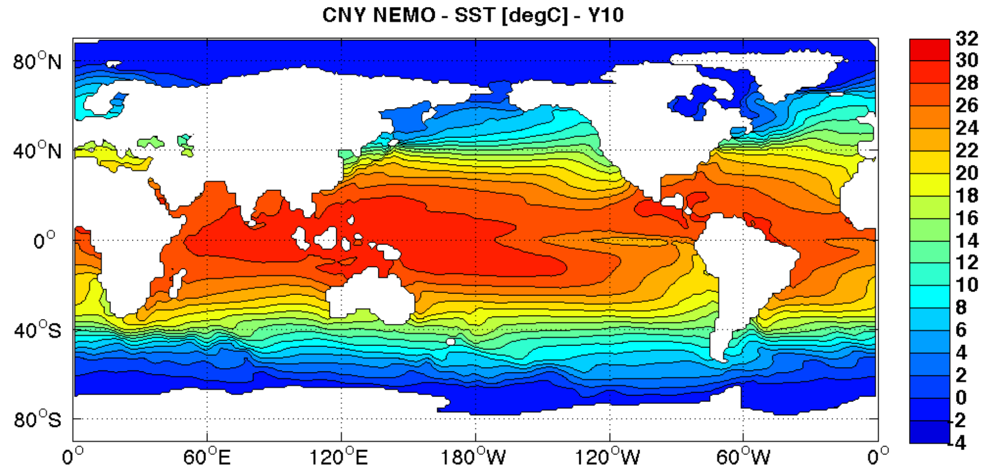
5. Preliminary results

Annual mean SST at year 10

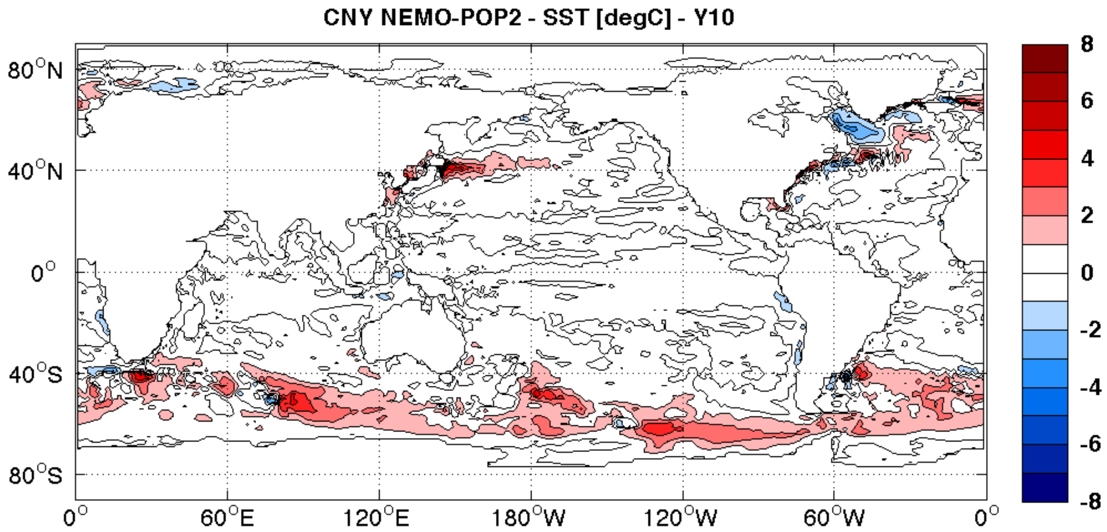
POP2



NEMO



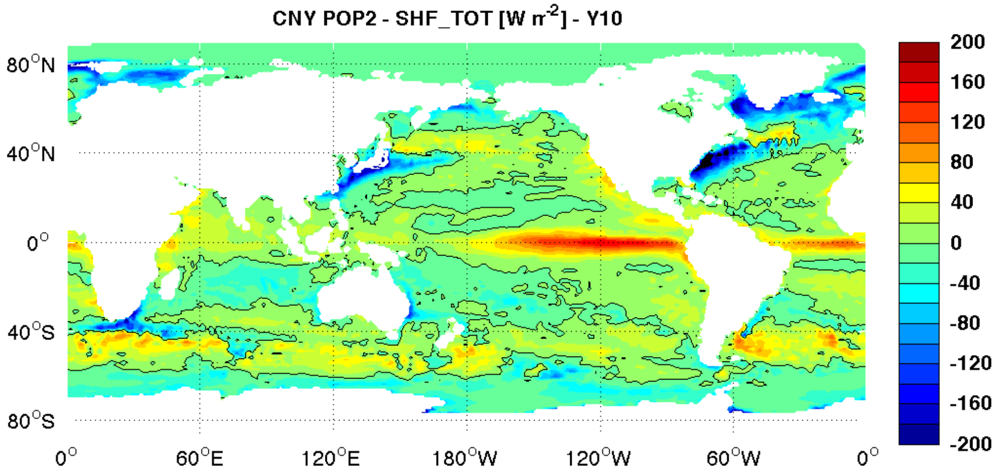
NEMO – POP2



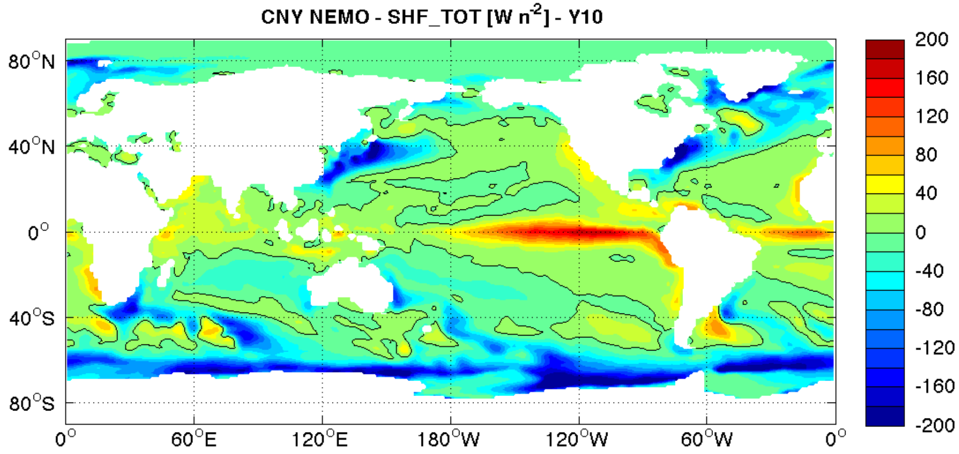
5. Preliminary results

Global annual mean total surface heat flux at year 10

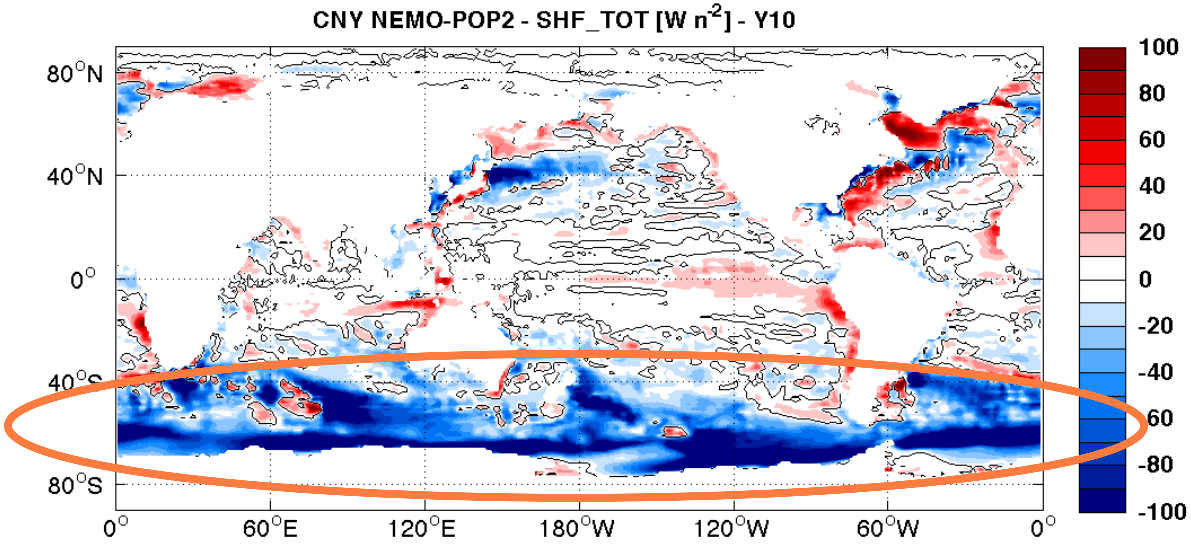
POP2



NEMO



NEMO – POP2



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The best is yet to come!

Stay tuned: piergiuseppe.fogli@cmcc.it

Thanks