



Centro Euro-Mediterraneo
sui Cambiamenti Climatici

www.cmcc.it

Sea ice modeling activities at CMCC

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PCWG Meeting 2024

NSF National Center for Atmospheric Research

February 6, 2024

About the CMCC



MISSION

To investigate and model our climate system and its interactions with society to provide reliable, rigorous, and timely scientific results to stimulate sustainable growth, protect the environment, and develop science-driven adaptation and mitigation policies in a changing climate. To develop foresight and quantitative analysis of our future planet and society.



Polar and sea ice researchers at CMCC



Dorotea Iovino



Lorenzo Zampieri



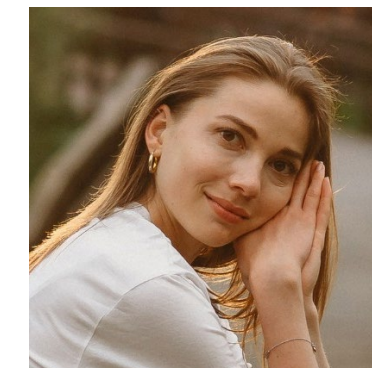
Andrea Cipollone



Francesco Cocetta



Elena Bianco



Julia Selivanova

We live in the **ESYDA Research Division**: Earth System modeling and Data Assimilation

Sea ice models within the CMCC

CICE
CESM family

CMCC Earth System Model
(CMIP6, SIMIP, etc.)

Seasonal to Decadal
Prediction System

OMPI2 runs

LIM / SI3
NEMO family

High-resolution OMIP-type
runs

Operational ocean
predictions

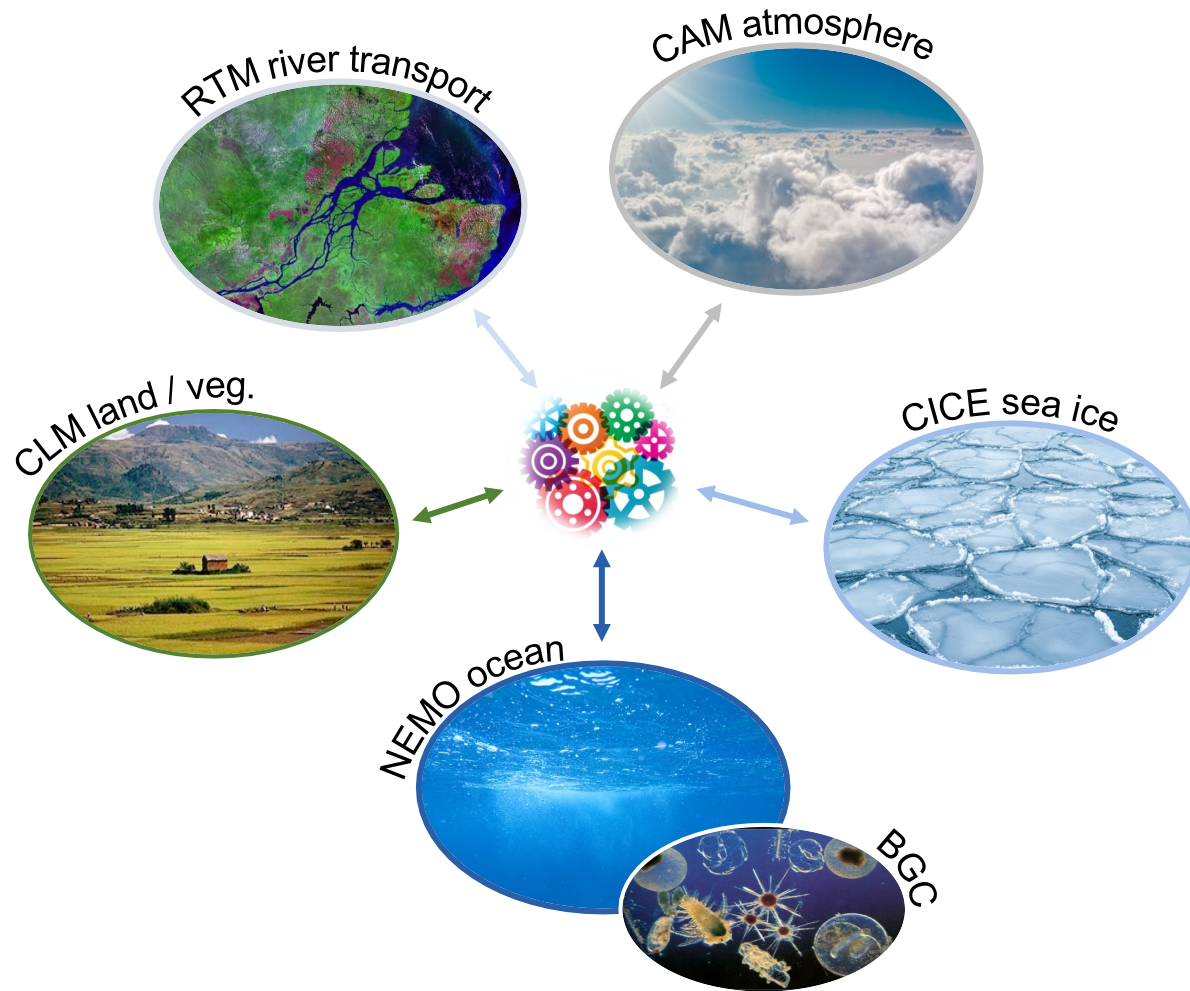
Unstructured
Sea Ice Model

Global Coastal Ocean
Simulations

What the future brings :)

Such model diversity brings pros and cons...

The CMCC Earth System Model for CMIP6



Community Atmosphere Model CAM5.3
(1° and 1/4° and 30 levels,
interactive/prescribed aerosols)

Community Land Model CLM4.5
(same grid as the atmospheric model)

River Transport Model RTM (0.5°)

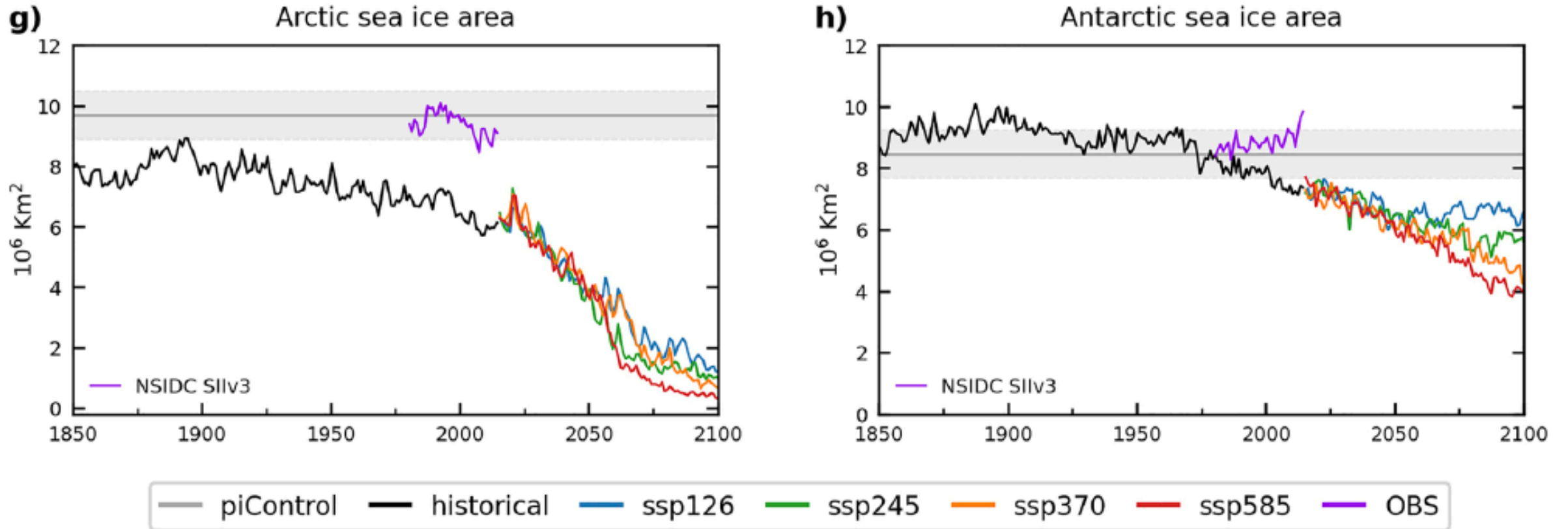
Biogeochemical Flux Model BFM5.1

Nucleus for European Modelling of the Ocean
NEMOv3.6 (1° and 1/4° and 50 levels)

Sea Ice Model CICE4
(multi-category, same resolution as ocean)

Ocean Model Intercomparison Project (OMIP-2)

The CMCC Earth System Model for CMIP6

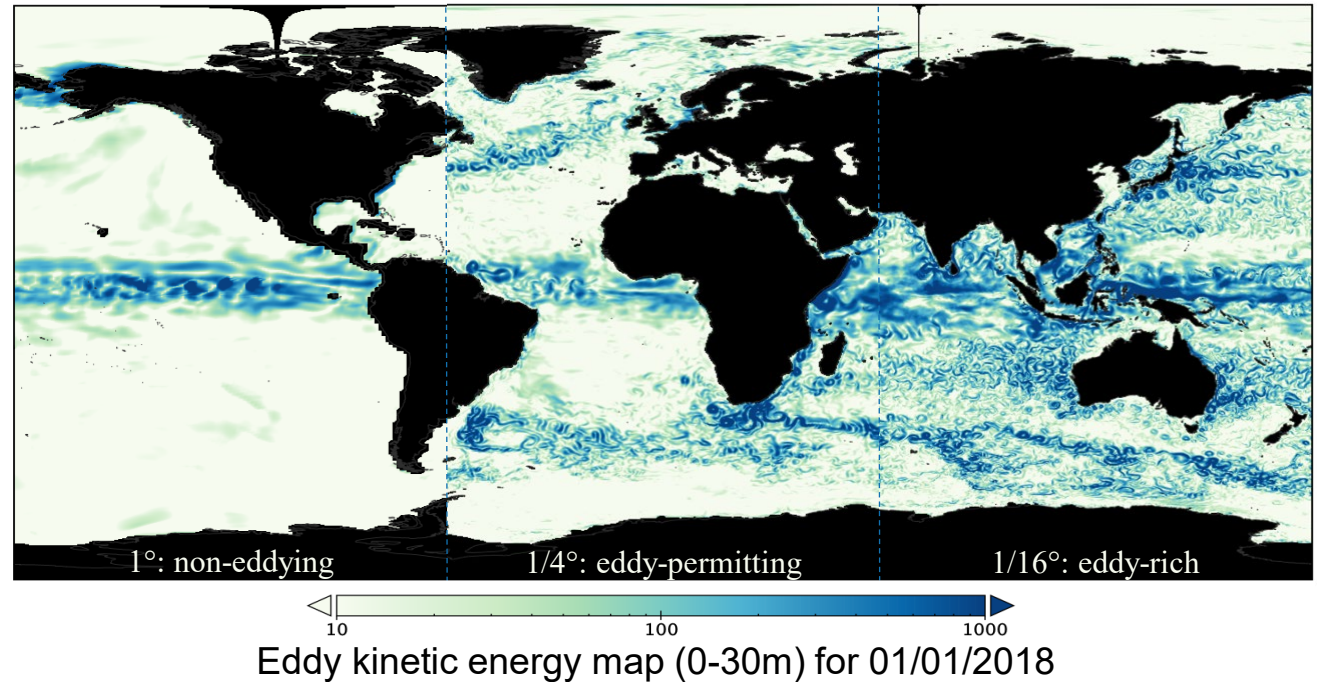


Lovato et al., 2022

High-Resolution NEMO Ocean and Sea Ice

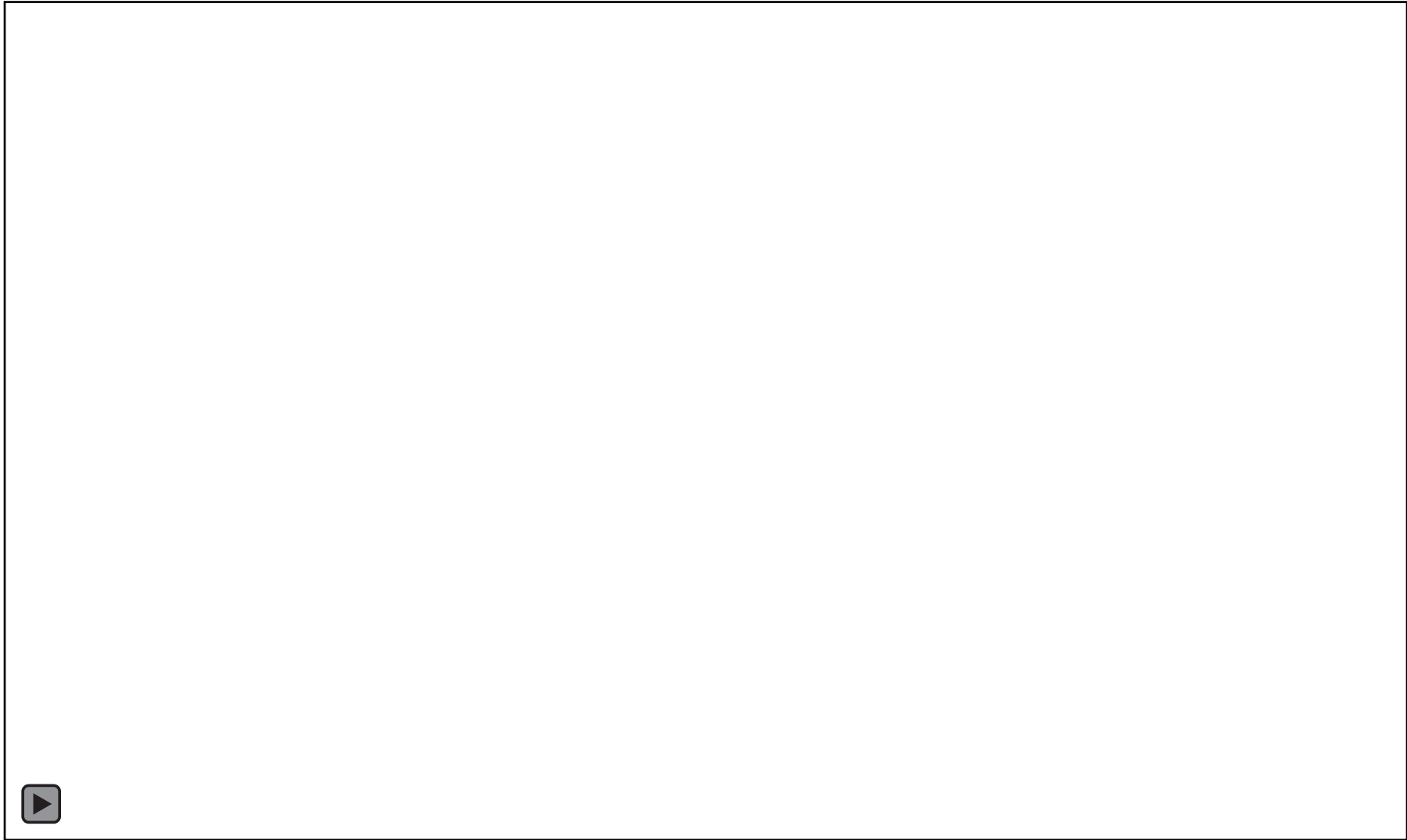
The simulation strategy follows as much as possible the OMIP-2 protocol that consists of simulating **six (only one for GLOB16)** repeating cycles of the atmospheric and river forcing with interannual variability (JRA55-do v1.4 from 1958 to 2018).

Iovino et al., 2023



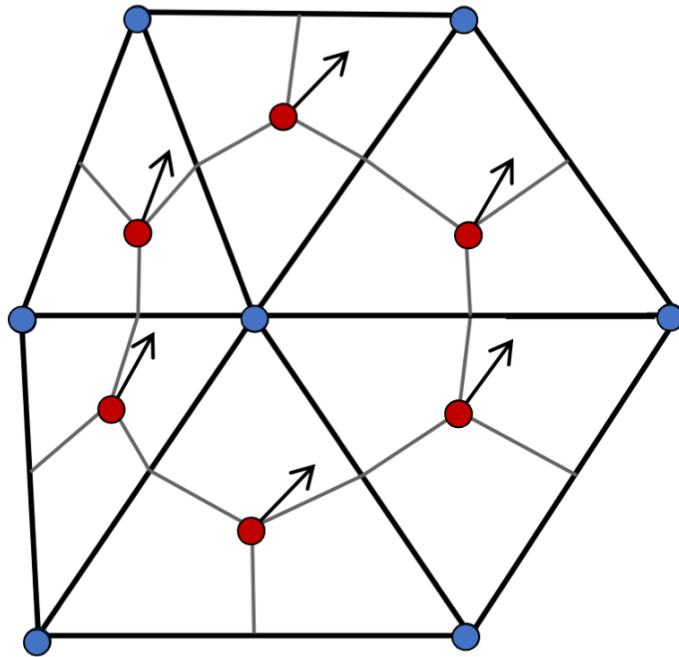
	Model	Horizontal grid points	Lateral spacing	Vertical levels	H_{\max}	Δz_{\min}	Δz_{\max}	Ocean time step	# cores (ocean/ice)	Wall time (h yr ⁻¹)
LR	ORCA1	360×291	1°	50	5903.9	1.05	409.6	3600	128/96	1.31
MR	ORCA025	1440×1050	0.25°	50	5903.9	1.05	409.6	1200	1008/972	4.44
HR	GLOB16 <i>(simplified sea ice model)</i>	5760×3962	0.0625°	98	6181.4	0.8	161.7	200	2098	94.22

High-Resolution NEMO Ocean

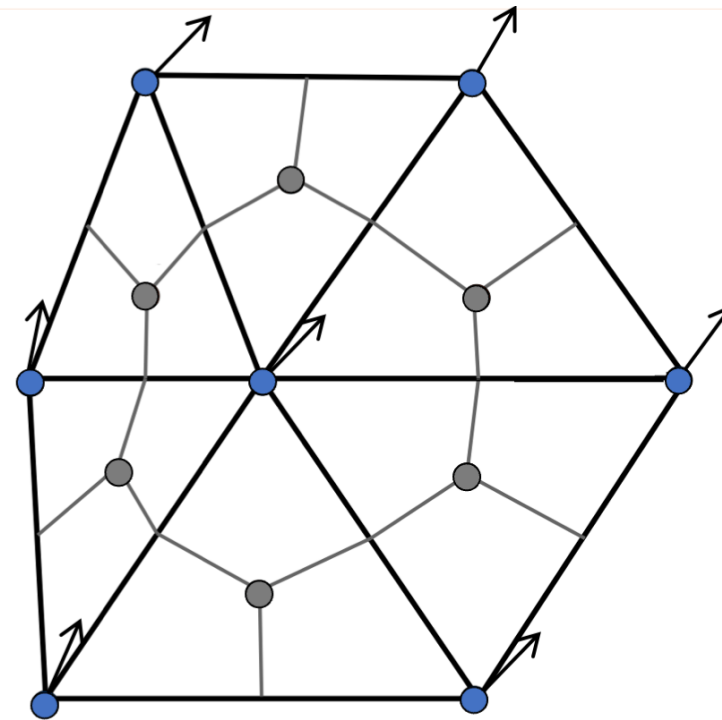


Modelling Sea Ice on Unstructured Meshes

MUSE = Multiscale Unstructured model for Simulating the earth water Environment



(a) Sea ice discretization as stored in memory



(b) Sea ice discretization for dynamics computations

MUSE Sea Ice Implementation



OCEAN to SEA ICE

sea surface temperature (sst)
sea surface salinity (sss)
sea surface slope (∇ssh)
ocean currents (u_{oce})



SEA ICE to OCEAN grid cell-averages

ice concentration (a_{ice})
freshwater flux from ice to ocean (f_{fw})
net heat flux from ice to ocean (f_{hocn})
shortwave through ice to ocean (f_{swthru})
freezing/melting potential ($frzmlt$)

Thermodynamic Simulation (Icepak)



Thermodynamic evolution of **sea ice concentration** and **thickness**
in a **2019** ocean and sea ice simulation forced by **ERA5** atmospheric reanalysis.

Advection testcase

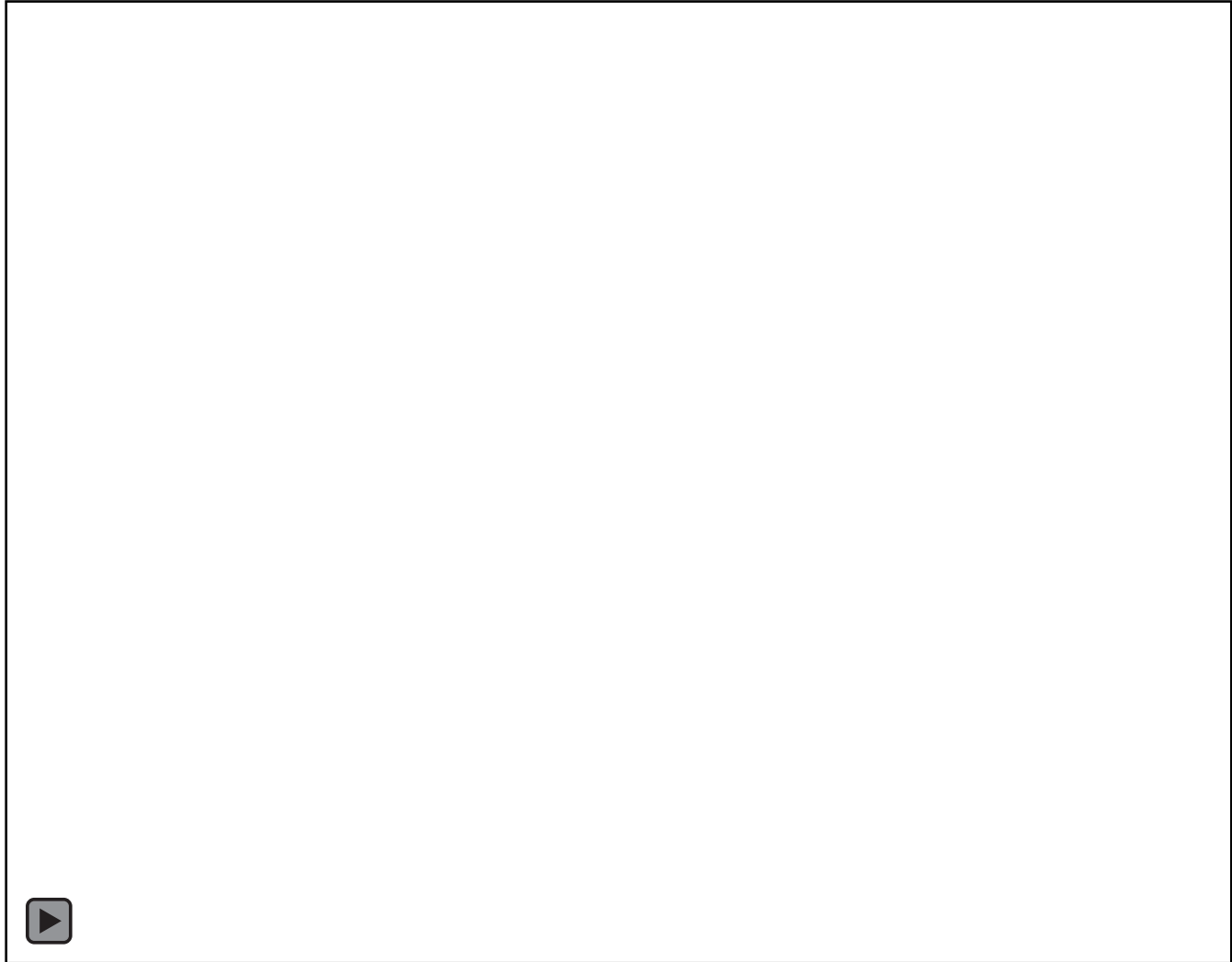
Finite Element-Flux Corrected Transport

$$\frac{\partial e_{ink}}{\partial t} + \nabla \cdot (e_{ink} \mathbf{u}) = 0,$$

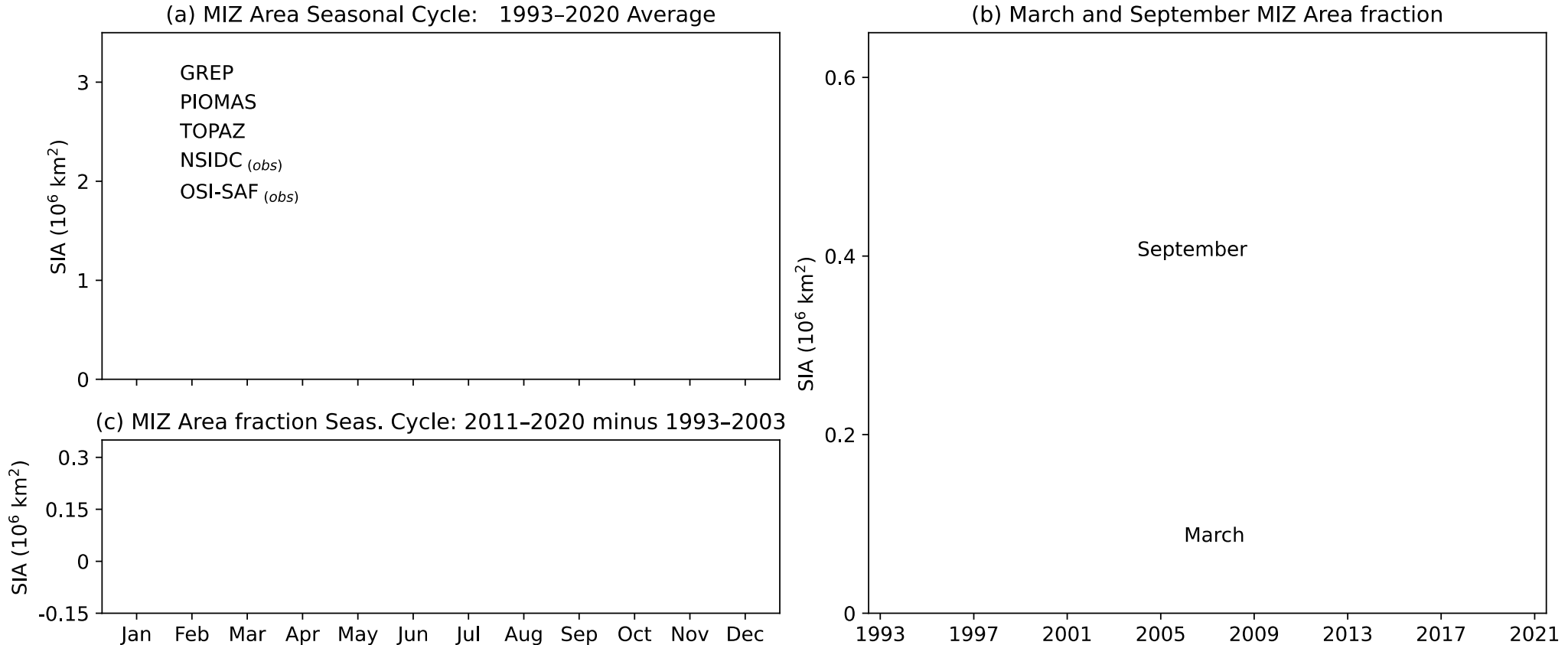
– High (TG) and Low order solutions are combined to further remove dissipative errors of the TG method

– Second-order convergence in idealized advection tests

FE-FCT by Löhner et al., 1987



Other sea ice activities at CMCC: Investigating Reanalyses



Cocetta et al. (in preparation)



12th International Workshop on Sea Ice Modelling, Assimilation, Observations, Predictions and Verification (**IICWG-DA-12**) will take place in Frascati on 5-6-7 November 2024, at ESRIN (Frascati), the ESA Centre for Earth Observation

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