On the effect of grid resolutions and mixing schemes on vertical dynamics in coastal ocean models: a case-study in a shallow, semi-enclosed basin (northern Adriatic Sea)

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Ocean Predict COSS-TT meeting
June 18th 2025 , Ifremer, Plouzané

OGS National Institute of Oceanography and Applied Geophysics

Summary

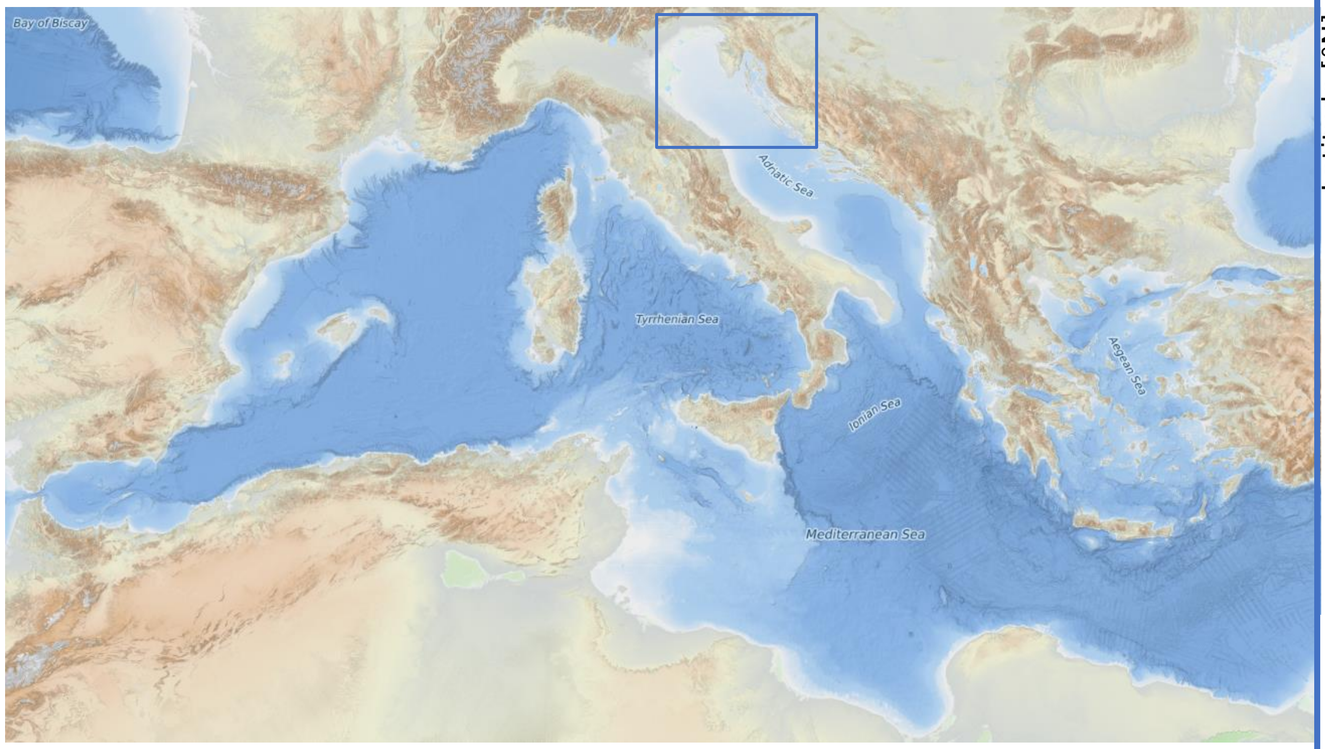
1. Introduction: study area and mesoscale
2. Methods: model and setups
3. Results: validation and mesoscale dynamics
4. Conclusions

Northern Adriatic Sea (NAS)

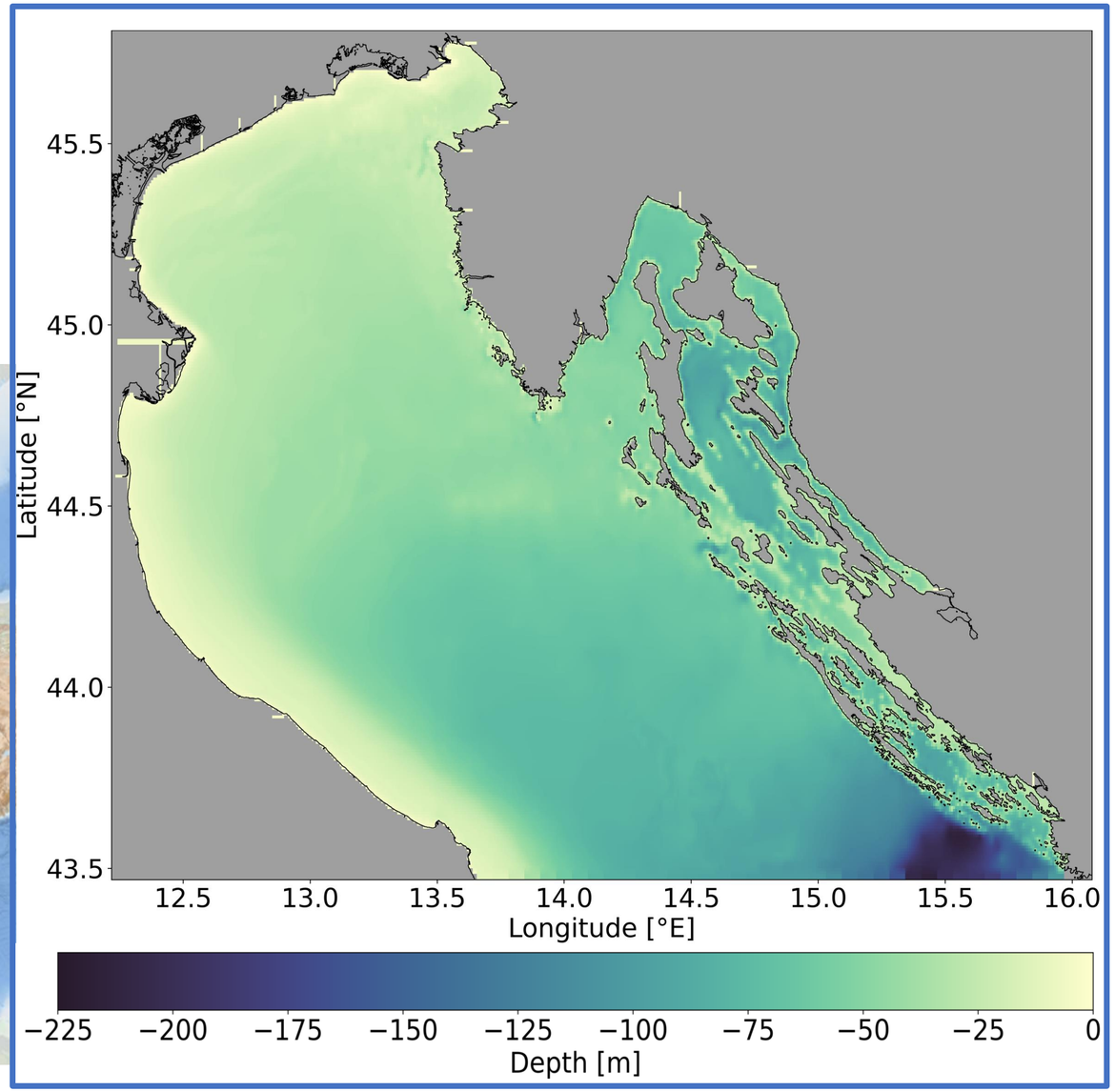
Marginal sea, continental shelf, **shallow** (~ 50 m)

Northernmost part of the **Mediterranean**

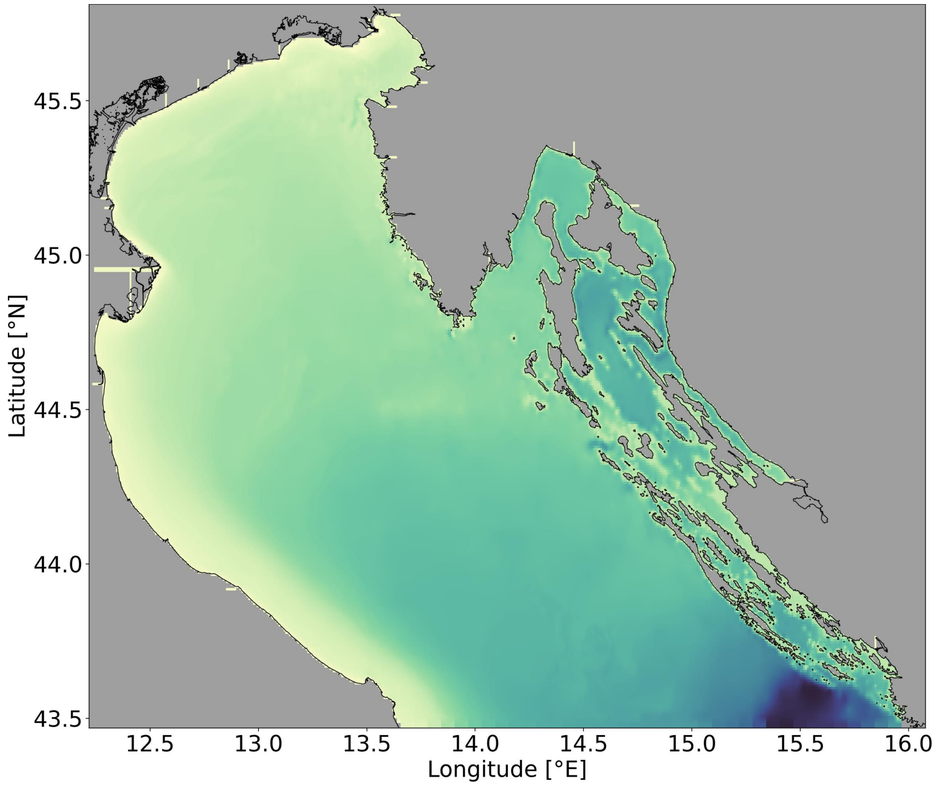
Physical, biological and socio-economic **relevance**



Credits: EMODnet bathymetry



NAS forcings



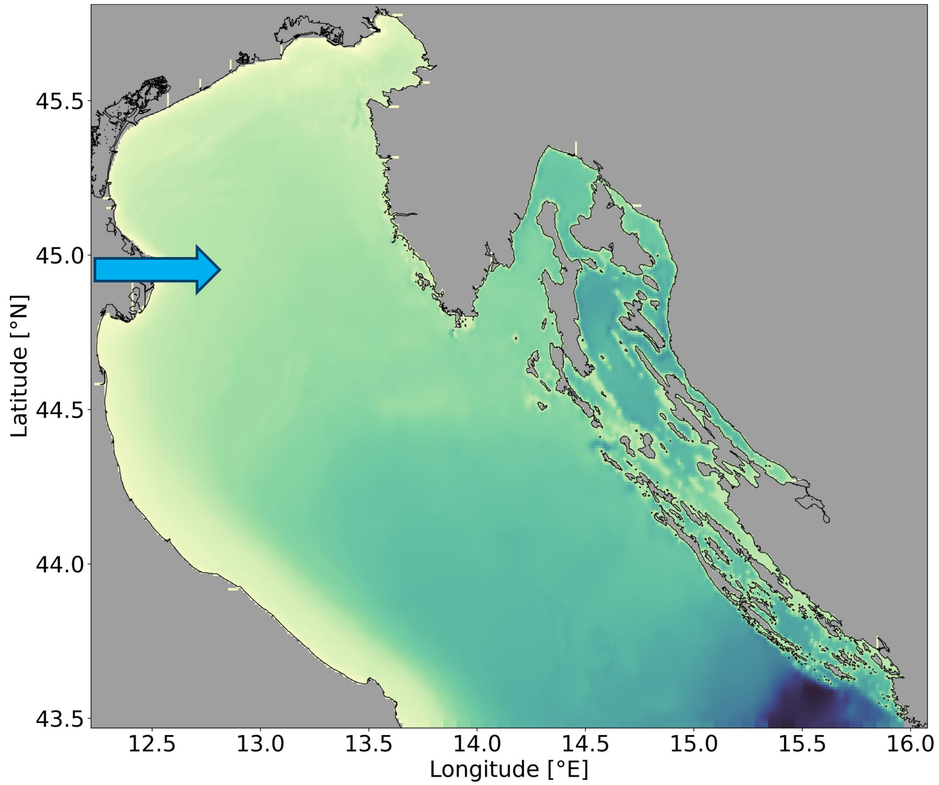
NAS forcings

Freshwater fluxes

NAS as **ROFI**:

freshwater from

many rivers (e.g. Po)



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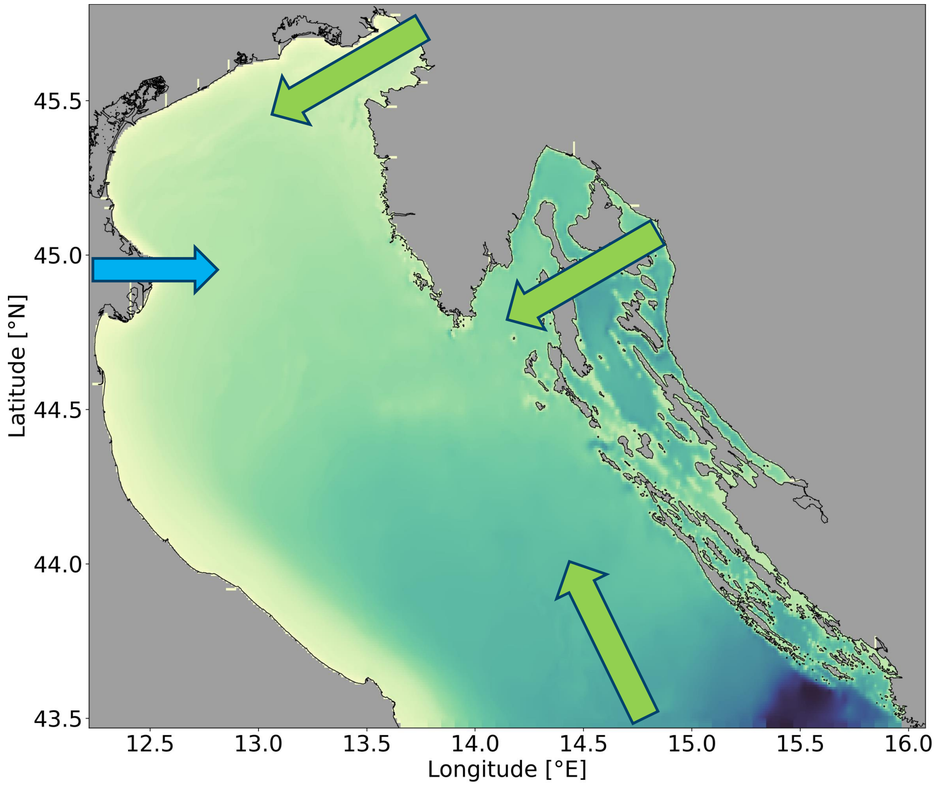

Air-sea fluxes

Wind regime (Bora):

dense water

formation

NAS forcings

Freshwater fluxes

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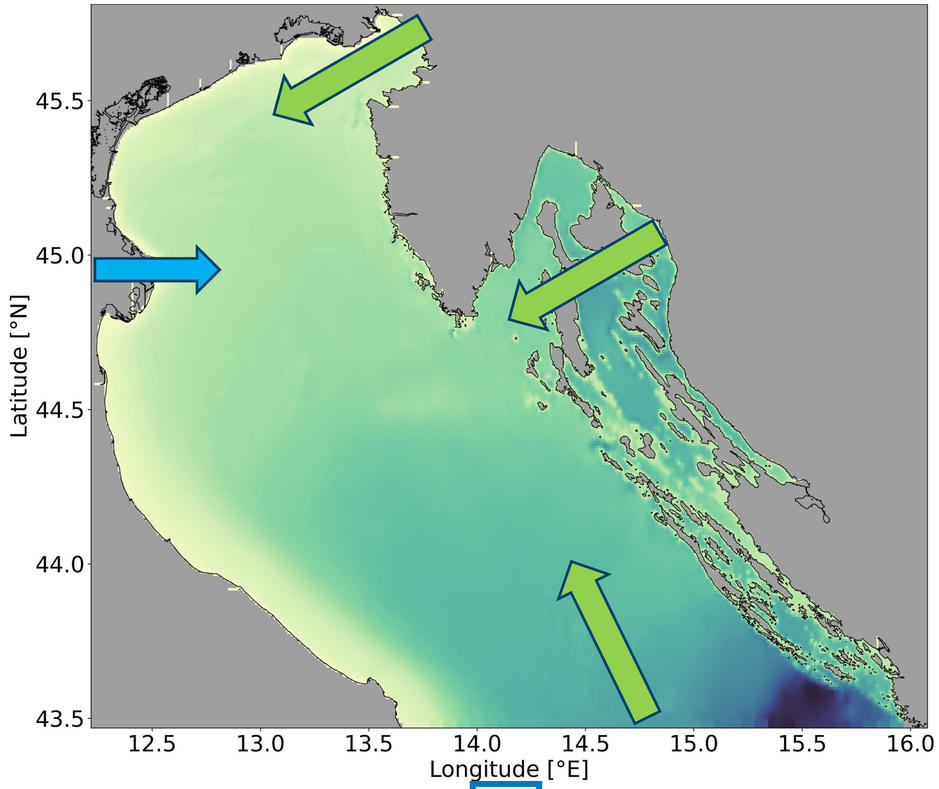

Air-sea fluxes

Wind regime (Bora):

dense water

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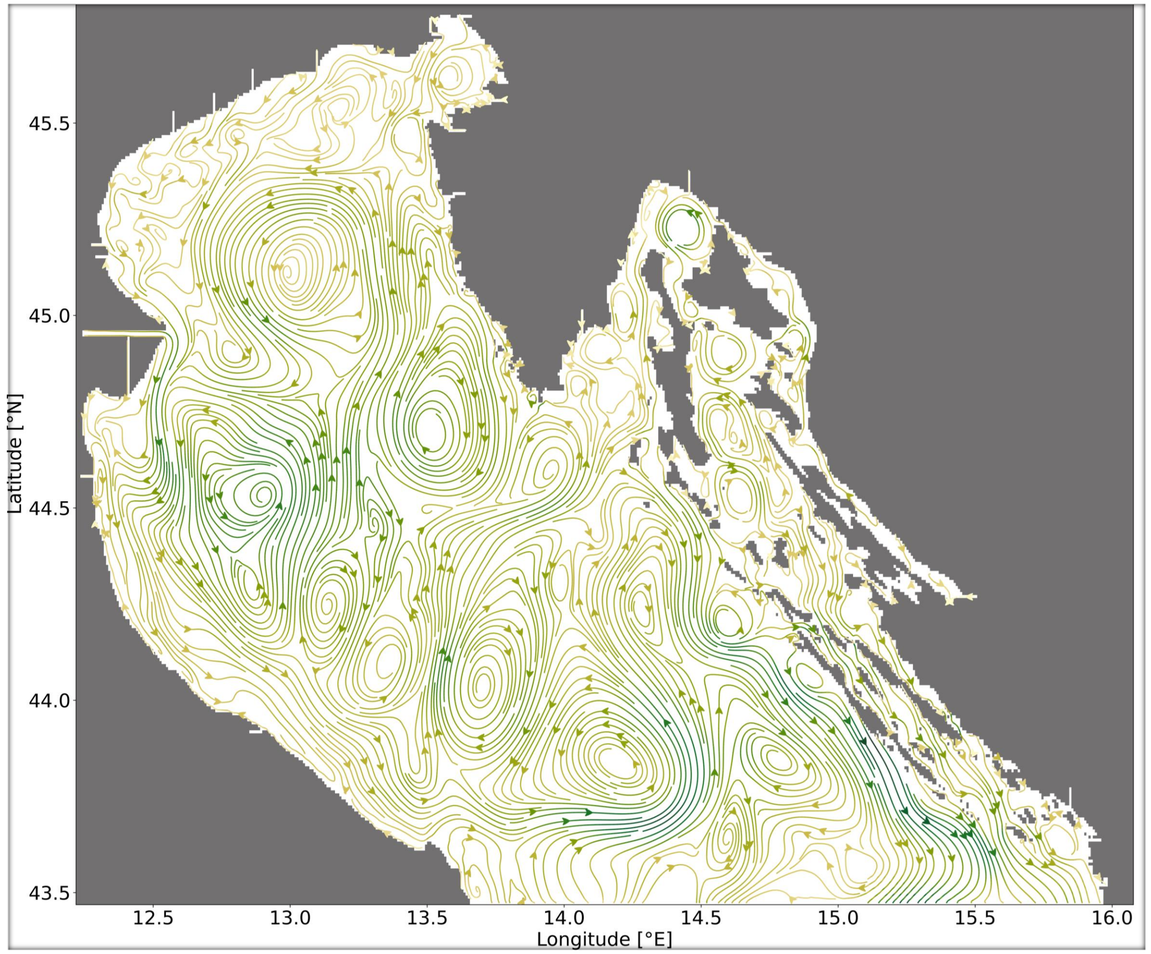
NAS as a **coastal modelling laboratory**

Mesoscale and stratification

Rossby radius of deformation: length scale

$$R_{Ro} = \frac{1}{f}\sqrt{\frac{\Delta\rho}{\rho_0}gh}$$



Average surface circulation, from July 12 to July 14 2018 as simulated by the MITgcm

Mesoscale and stratification

Rossby radius of deformation: length scale

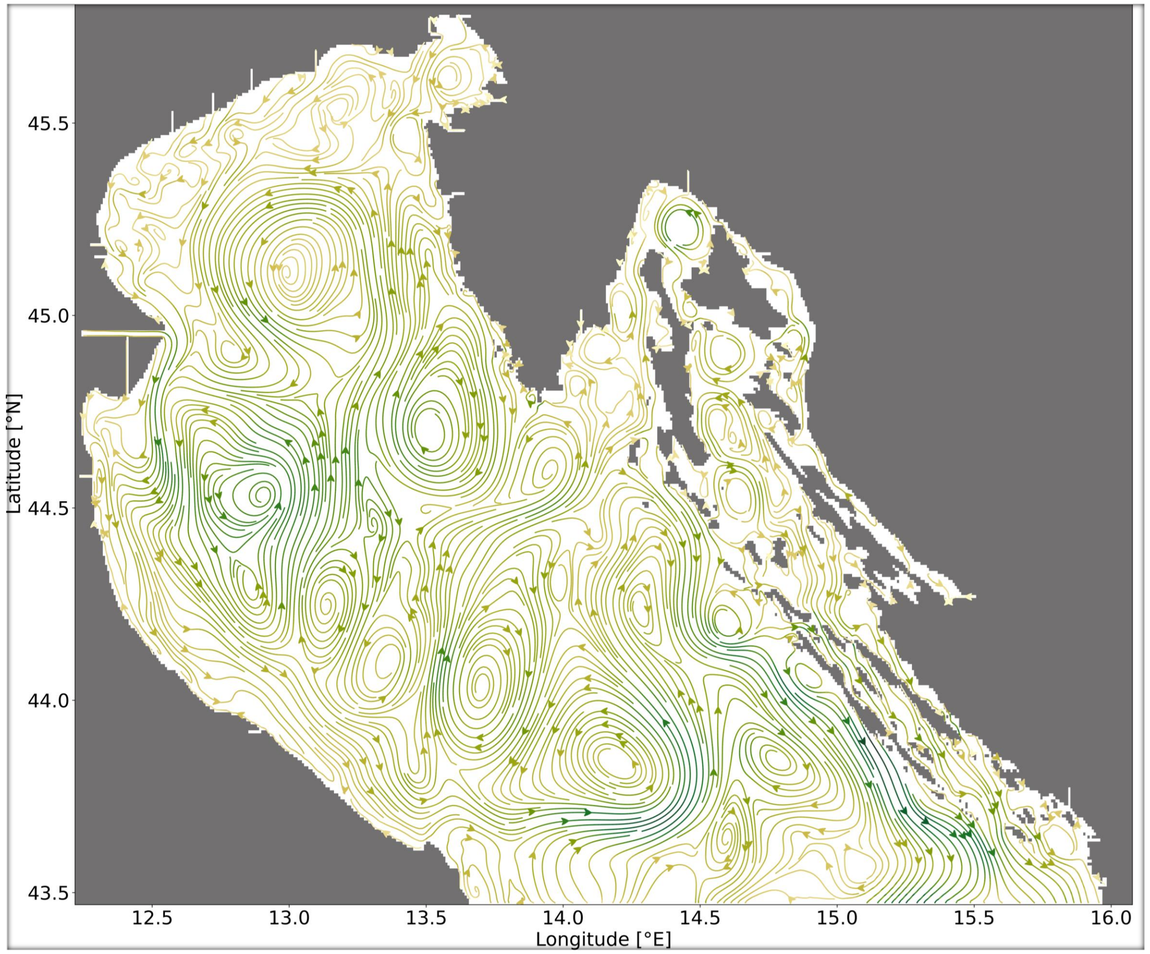
$$R_{Ro} = \frac{1}{f}\sqrt{\frac{\Delta\rho}{\rho_0}gh}$$

Function of **stratification** (Δρ)

Contains most of oceans' **kinetic** energy

Contributes to **transport** tracers and water masses

Need for **high resolution** modelling



Average surface circulation, from July 12 to July 14 2018 as simulated by the MITgcm

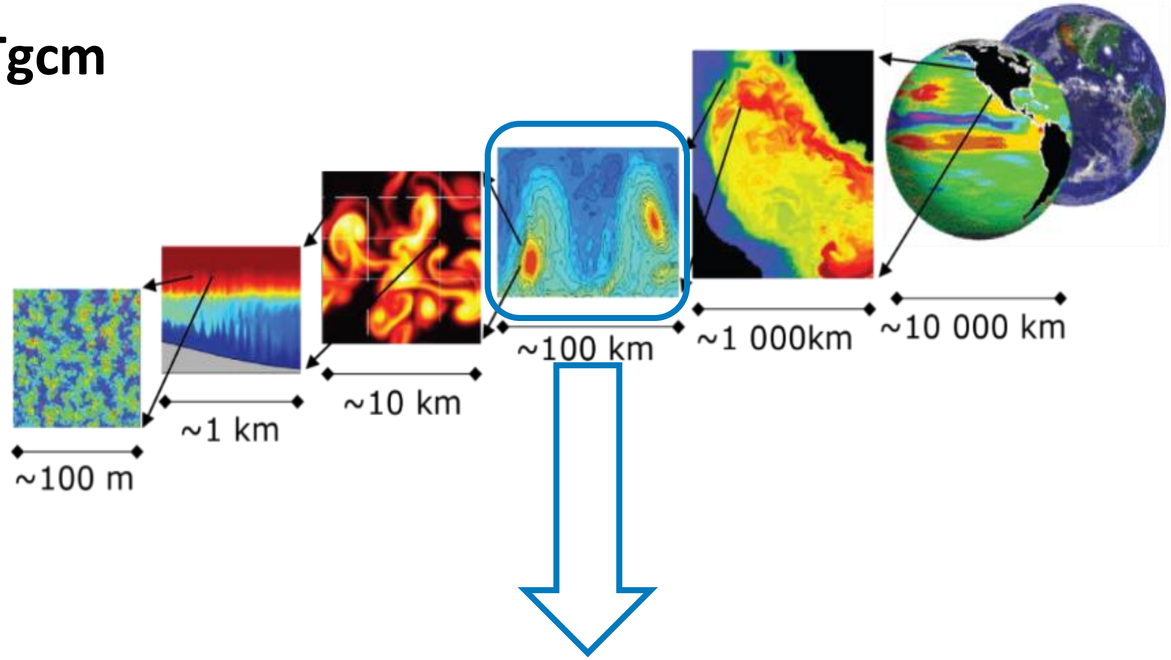
Goal

Investigate role of **vertical** physics (grid & mixing) in ROFI models:

1. Comparison with data ⇒ **water column** properties (e.g. stratification)
2. Study of the **mesoscale** field ⇒ important for transport (e.g. nutrients, pollutants)

Improvement in prediction skill

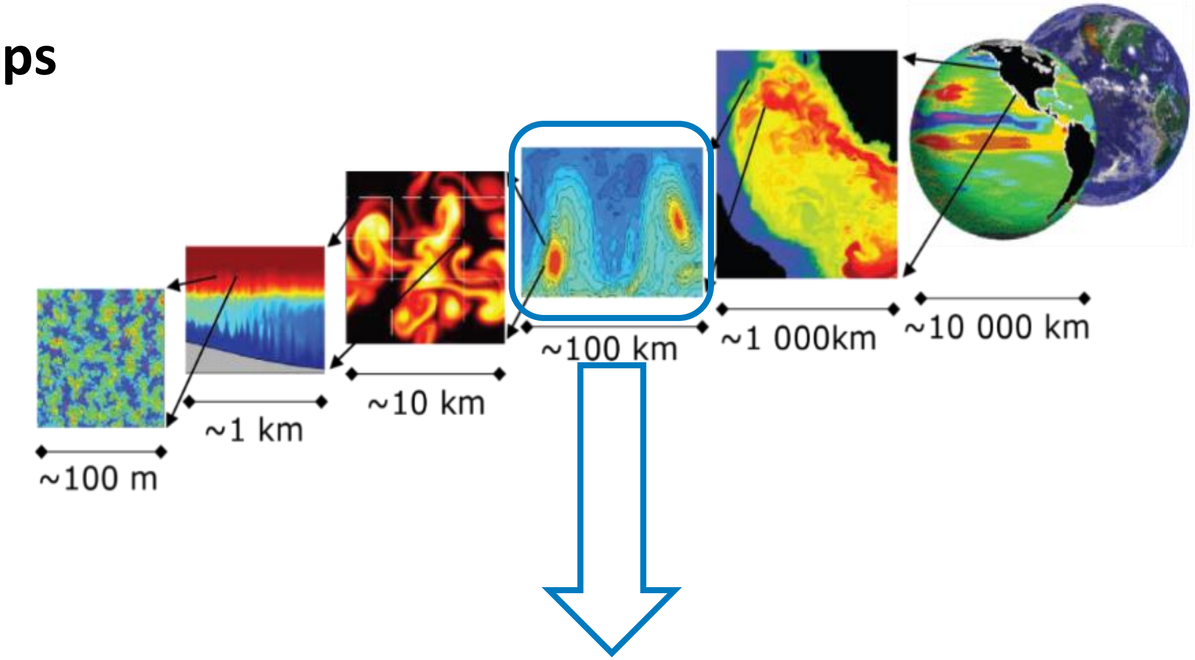
Modelling tool: MITgcm



- 1/128° horizontal resolution
- non hydrostatic

- COSMO/ICON atmospheric forcing (2.2 km)
- CMS boundary conditions
- 19 river outputs

Simulation setups



4 NAS 5-year hindcasts:

a) 2 vertical **grids** ("old" & "new")

b) 2 vertical **mixing** schemes (KPP & GGL)

	KPP	GGL
"old": 27 levels	**old + KPP**	**old + GGL**
"new": 59 levels	**new + KPP**	**new + GGL**

- 1/128° horizontal resolution
- non hydrostatic
- COSMO/ICON atmospheric forcing (2.2 km)
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- 19 river outputs

Manuscript in preparation for Ocean Modelling, setup availbale at 10.5281/zenodo.15622740

Comparison with observations: satellite

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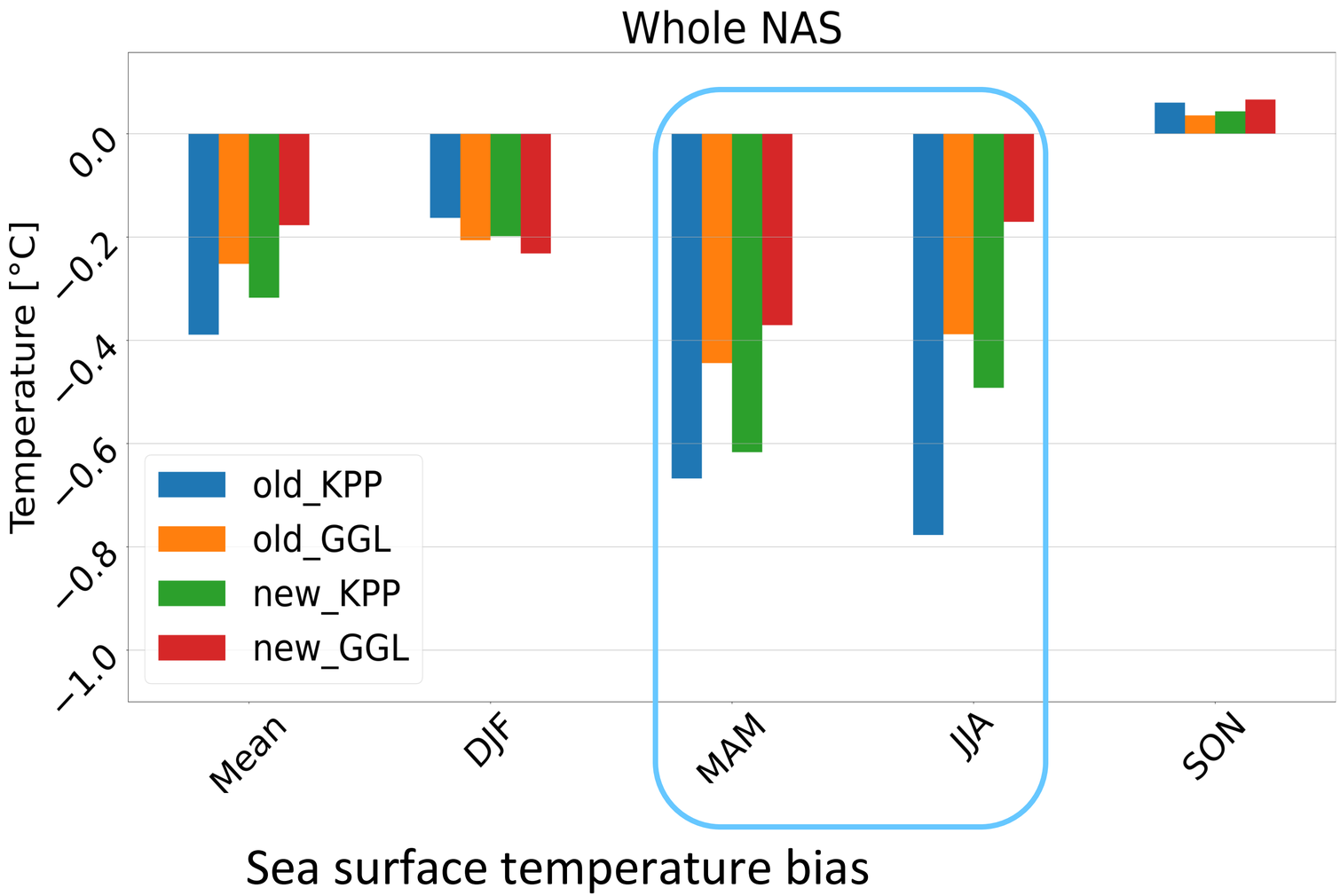


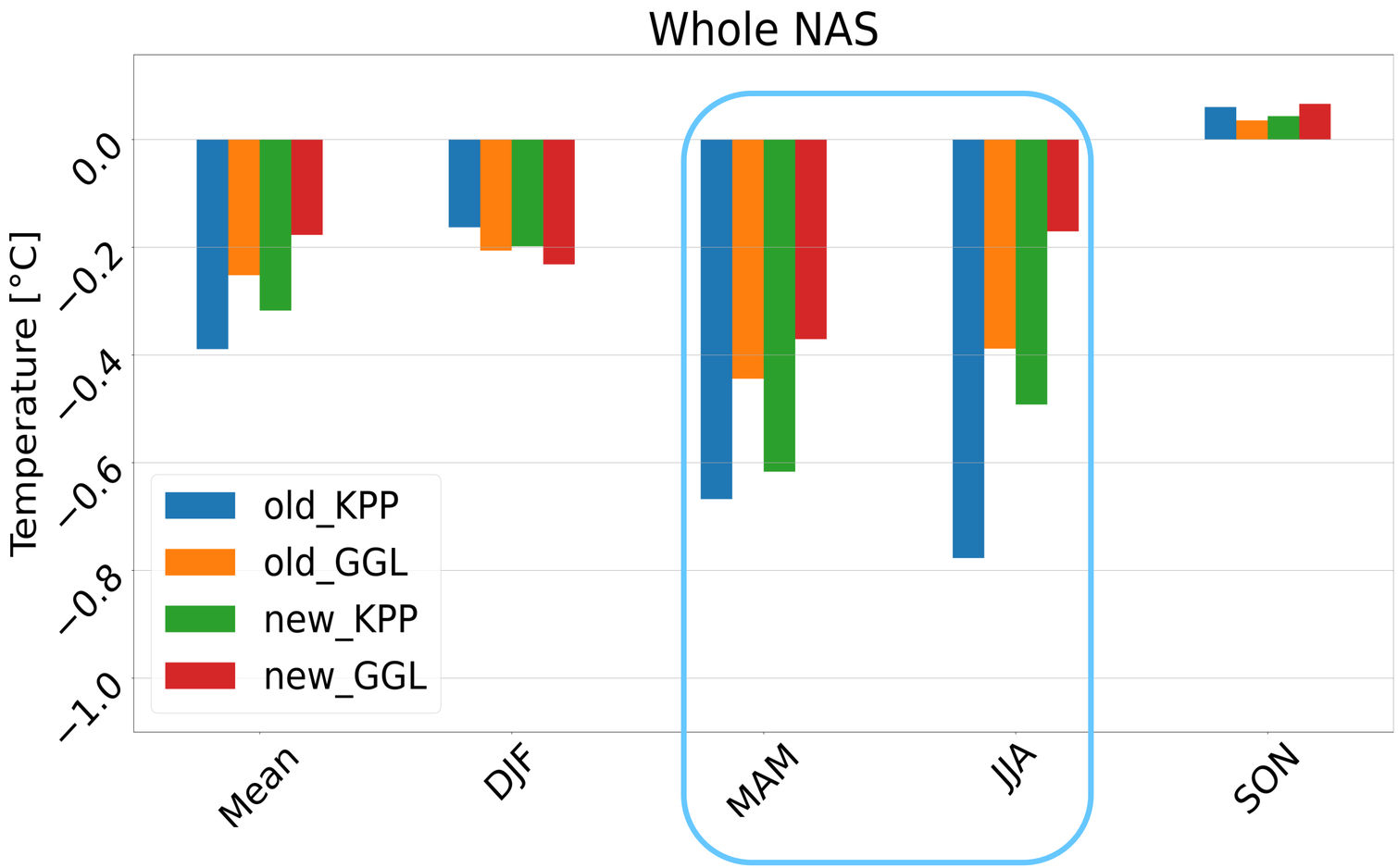
Sea surface temperature bias

Systematic **cold bias** (summer)

Reduced by **high-res** (old+KPP, old+GGL

→ new+KPP, new+GGL)

Comparison with observations: satellite



Sea surface temperature bias

Systematic **cold bias** (summer)

Reduced by **high-res** (old+KPP, old+GGL → new+KPP, new+GGL)

Reduced by different scheme (KPP → **GGL**)

old+GGL better than **new+KPP**

Comparison with observations: in situ

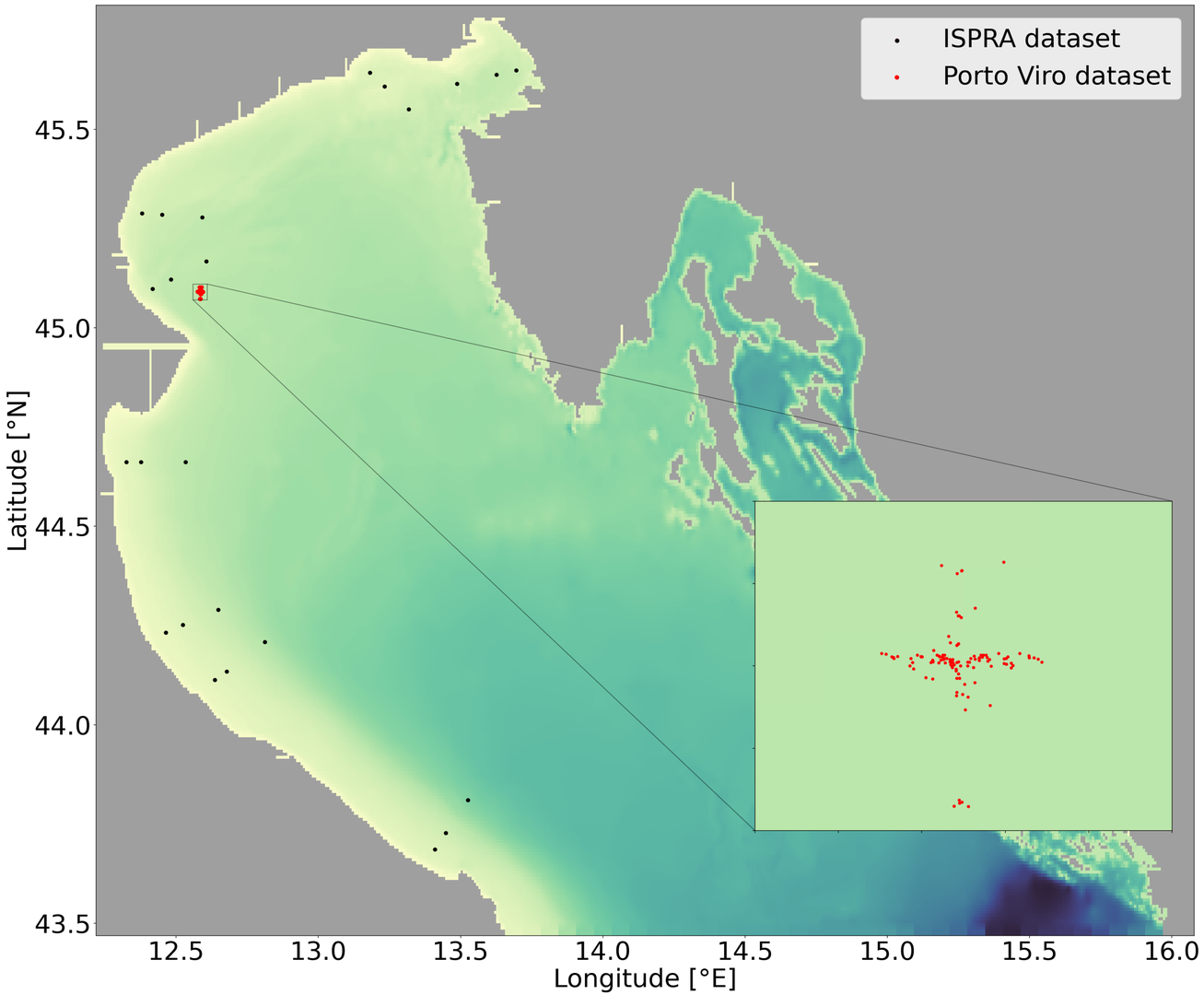
2 datasets

Vertical **profiles** of

temperature and **salinity**

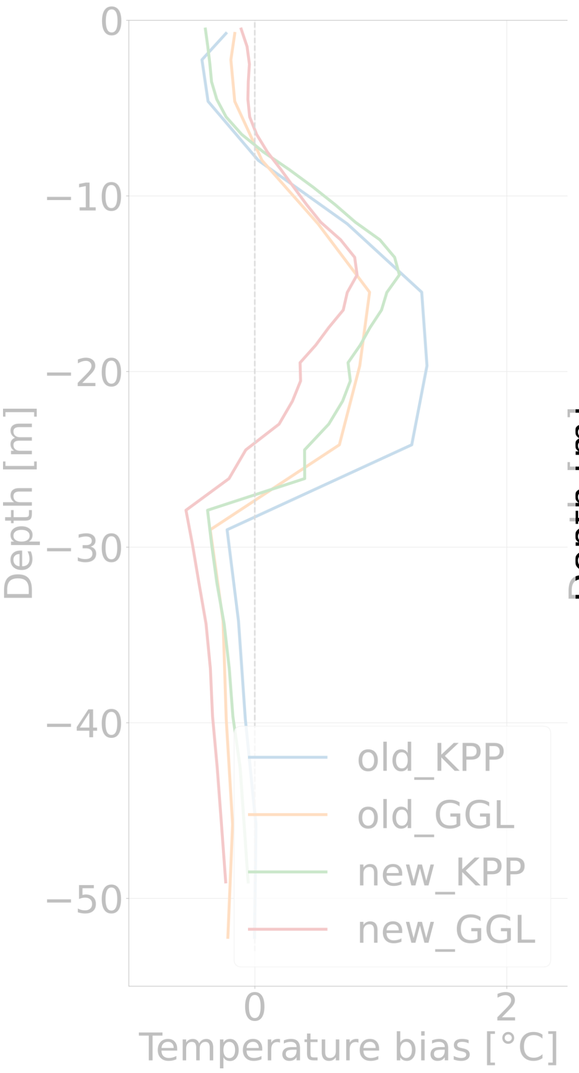
coastal band (< 12 nm) ⇒

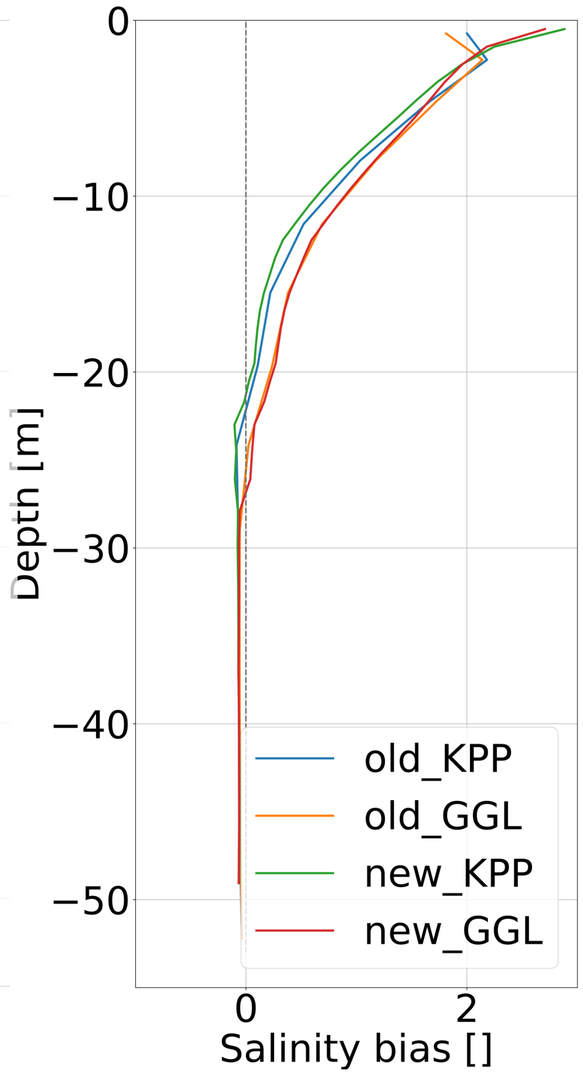
stress test for model skill



Credits: Adriatic LNG, ISPRA

Comparison with observations: in situ



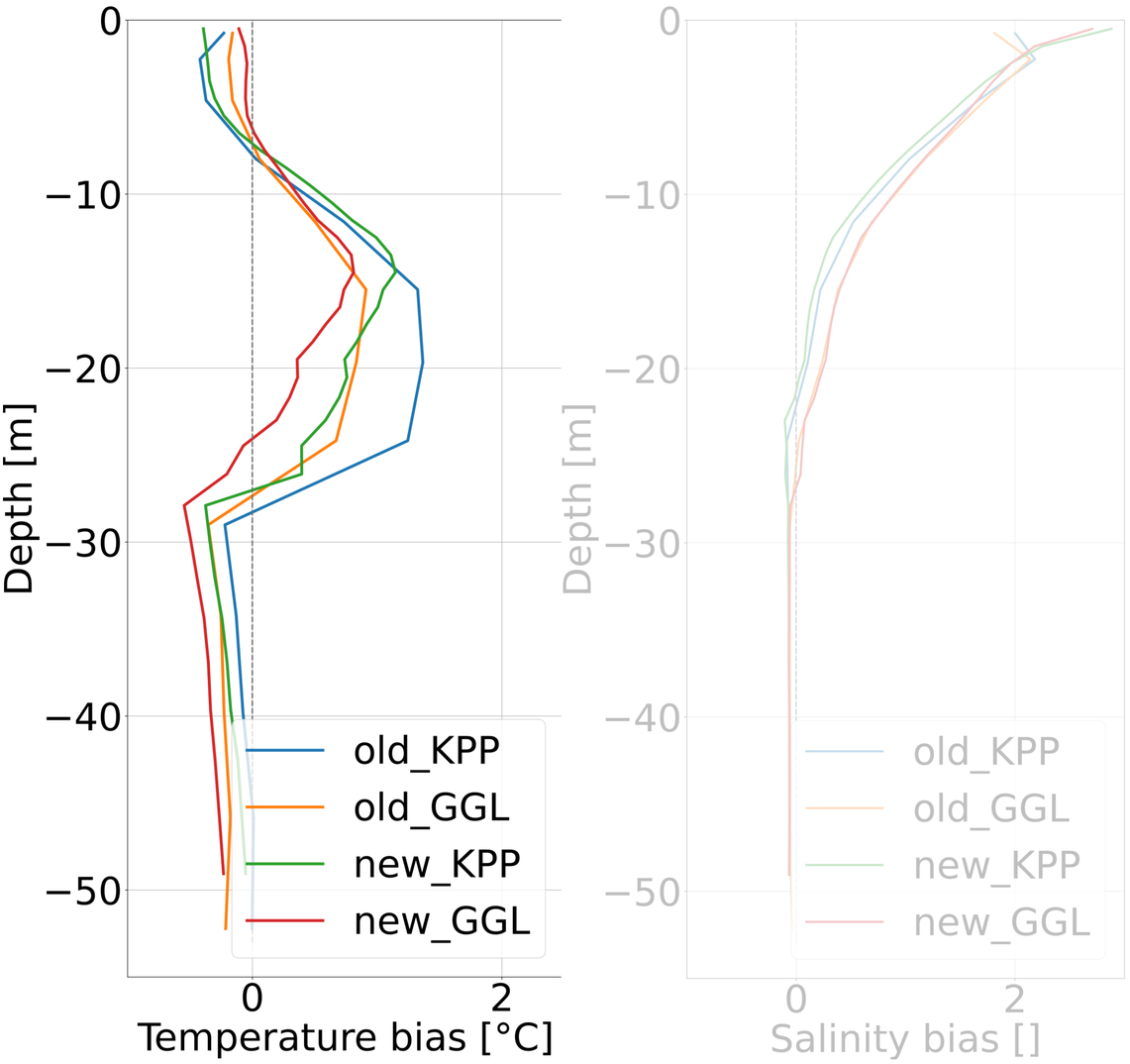


Salinity

improvement due to high-res

	Temperature bias [°C]	Temperature RMSD [°C]	Salinity bias []	Salinity RMSD []
old+KPP	0.553	2.121	1.108	2.162
old+GGL	0.404	1.718	1.171	2.083
new+KPP	0.420	1.934	0.827	1.759
new+GGL	0.295	1.582	0.986	1.754

Comparison with observations: in situ



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large **improvement** around **thermocline** depths

old+GGL ≃ new+KPP

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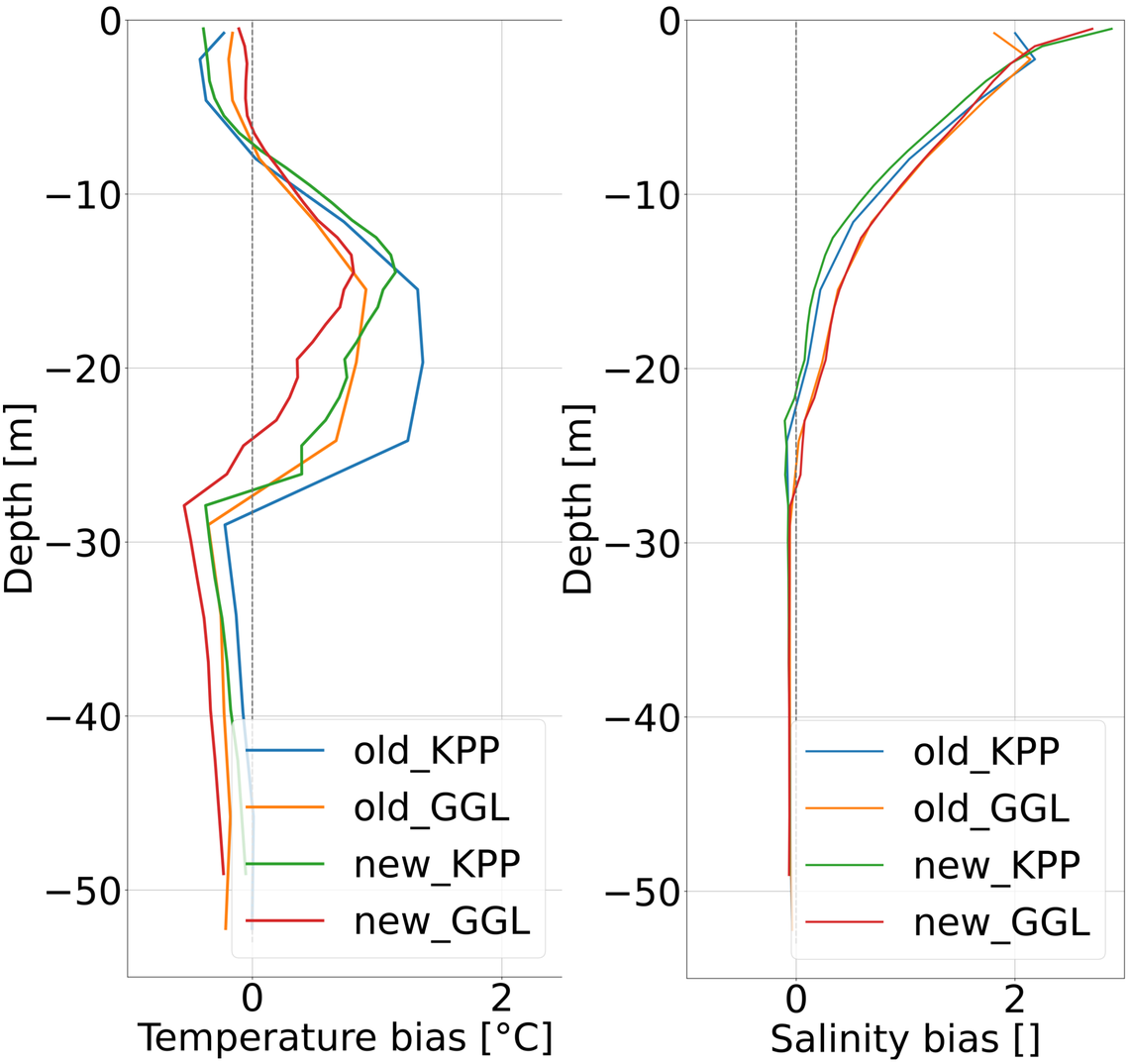

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new+GGL = best performing setup

Mesoscale dynamics: Rossby radius

Recap:

$$R_{Ro} = \frac{1}{f}\sqrt{\frac{\Delta\rho}{\rho_0}gh}$$

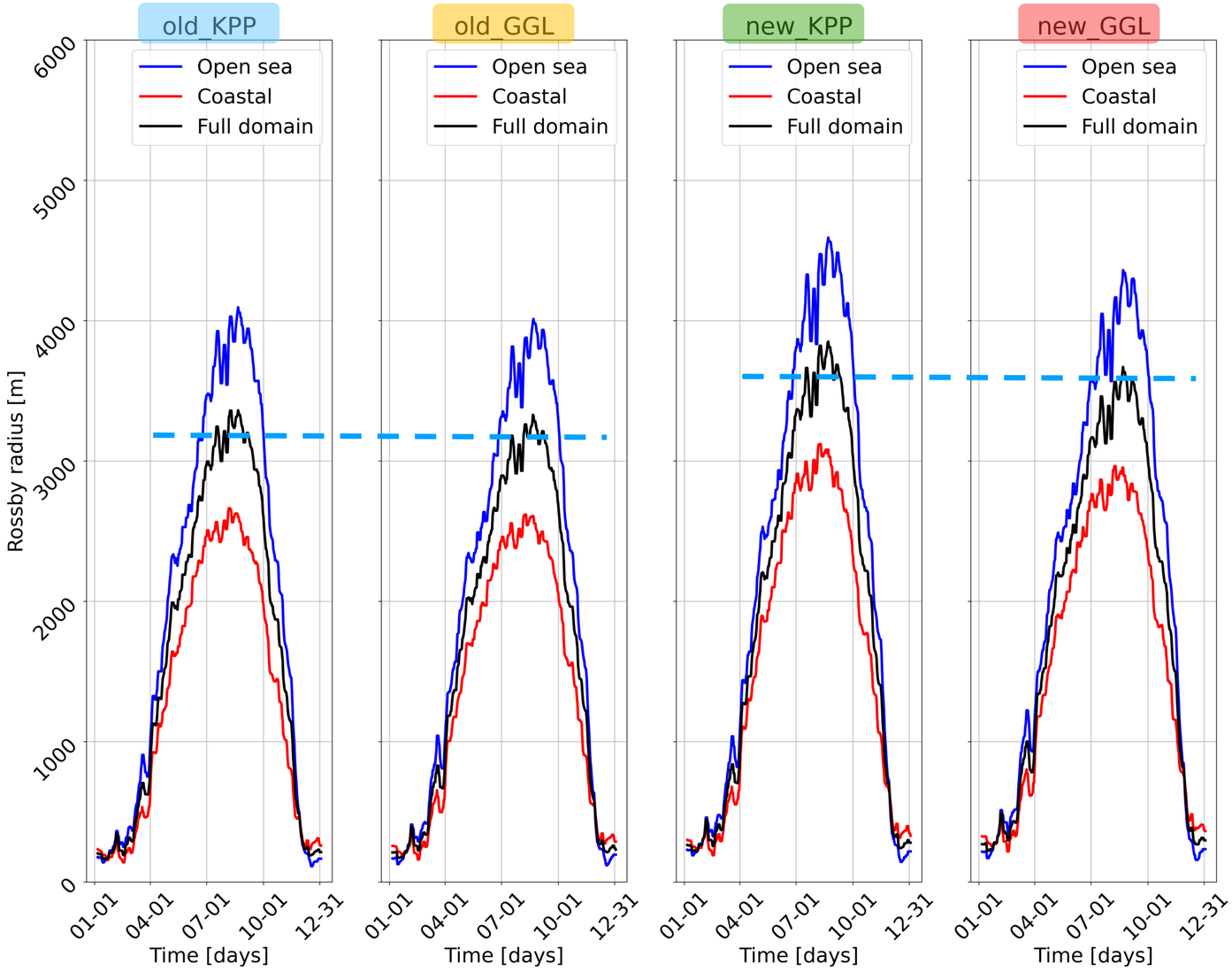
Mesoscale dynamics: Rossby radius

Recap:

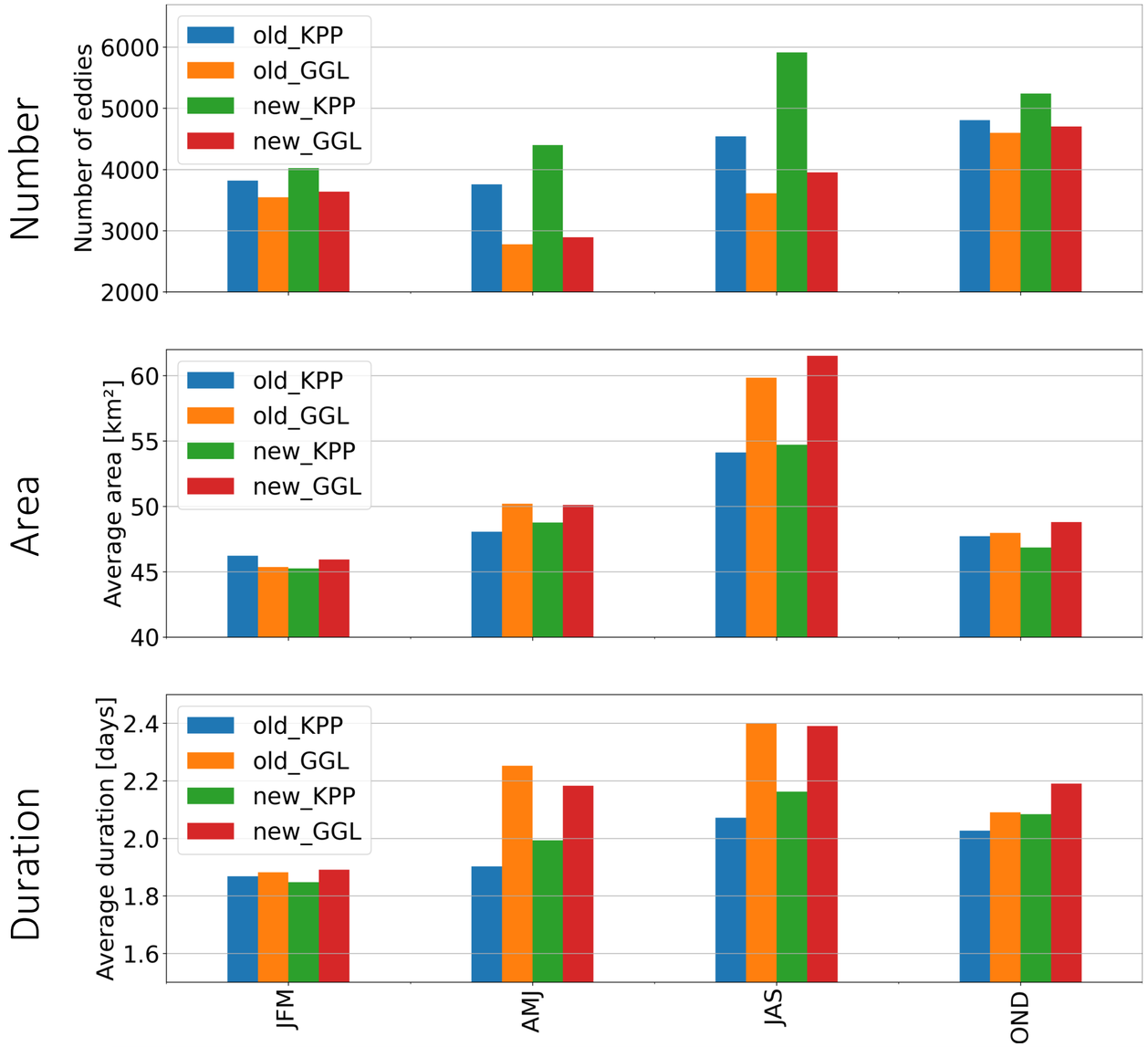
$$R_{Ro} = \frac{1}{f}\sqrt{\frac{\Delta\rho}{\rho_0}gh}$$

More sensitive to vertical **resolution** than mixing scheme:

resolution > scheme for **salinity** ⇒ **density** gradient ⇒ **Rossby radius**

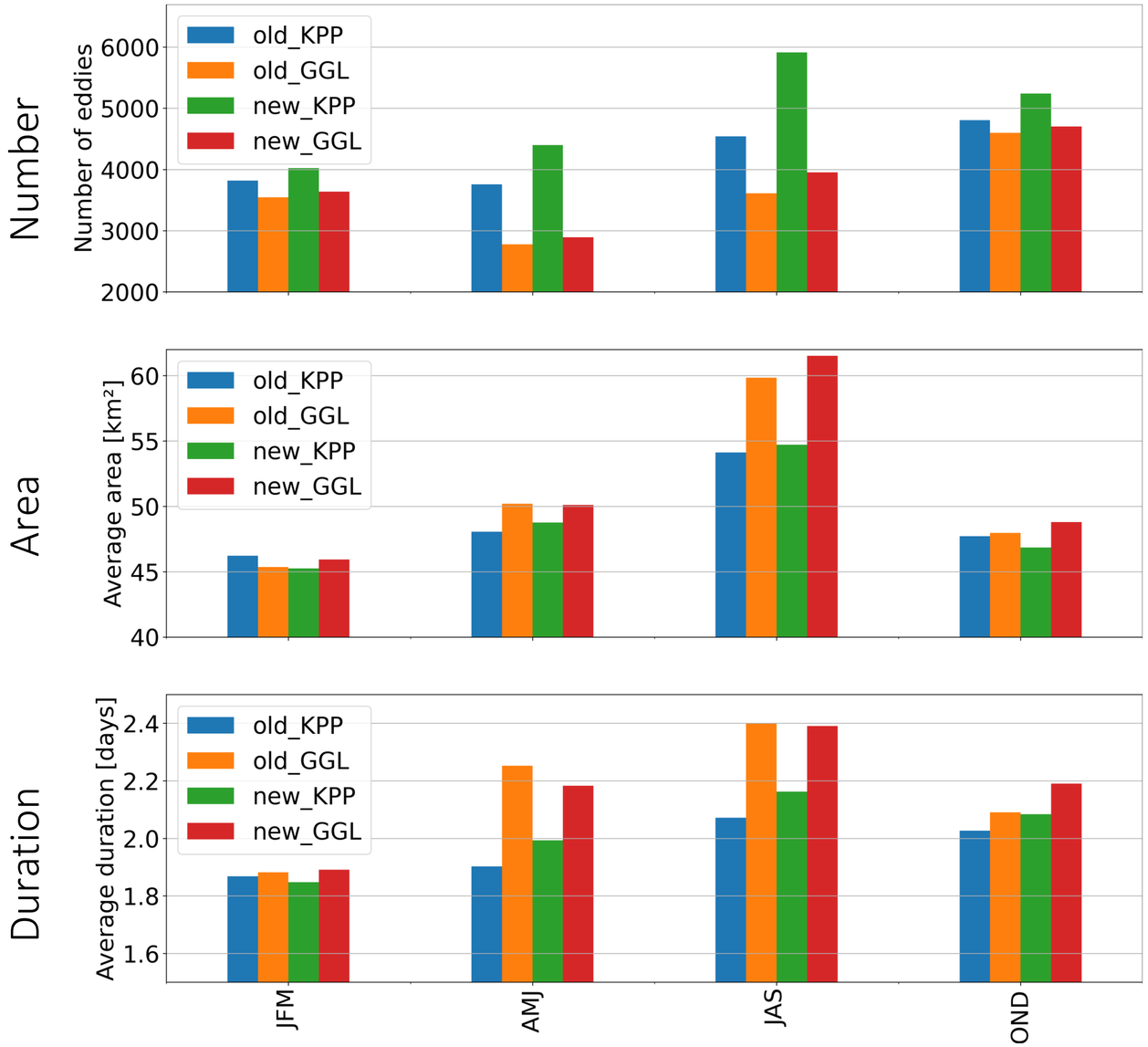


Mesoscale dynamics: Eddy field



Detection and tracking: **Okubo-Weiss** parameter

Mesoscale dynamics: Eddy field



Detection and tracking: **Okubo-Weiss** parameter

More **frequent** with KPP

Longer-lived and **larger** with GGL

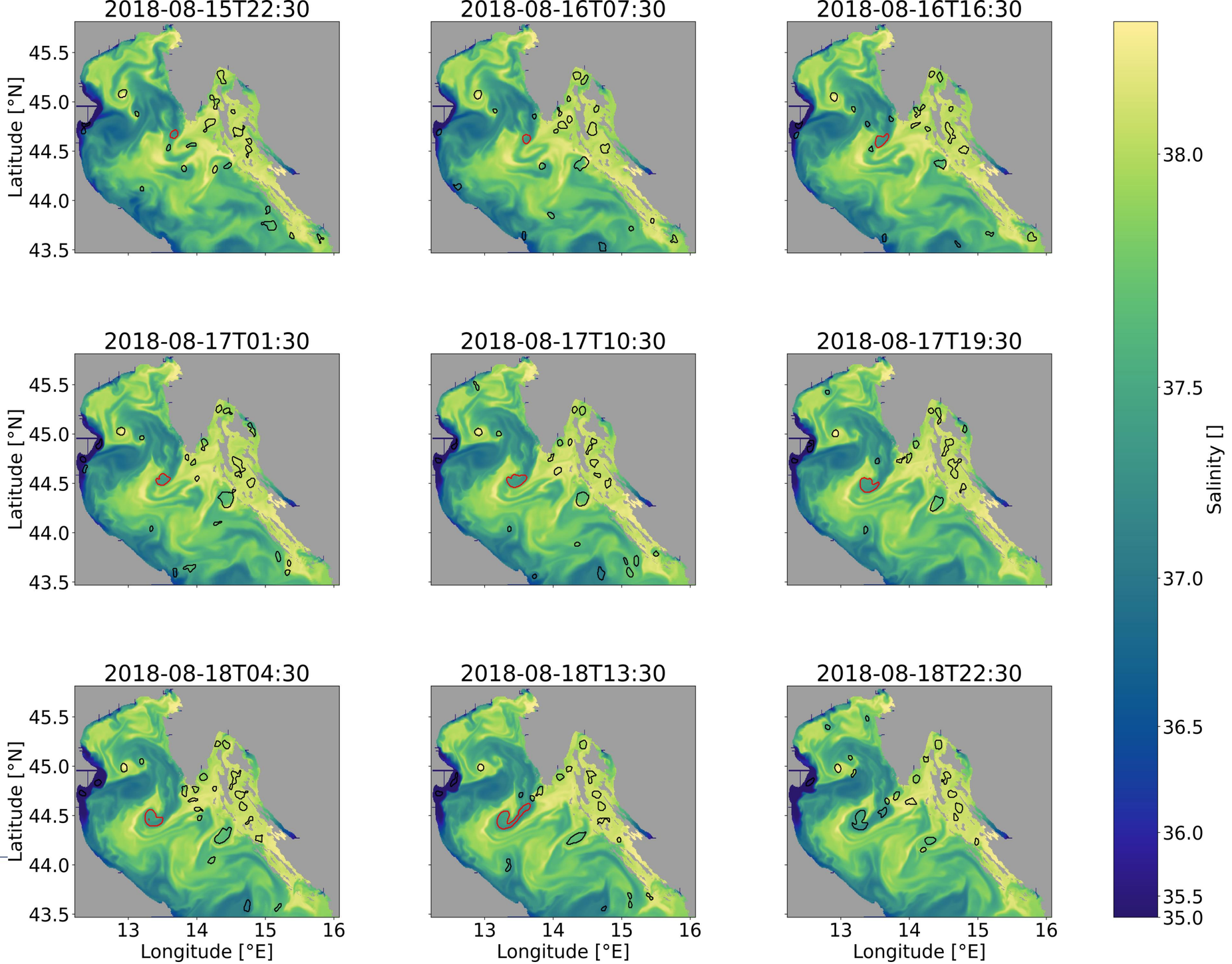
Less stable **stratification** ⇒

eddies decay more easily with **KPP**

Mesoscale dynamics: Eddy field

Eddies contribute in **transport** of tracers (e.g. salinity) in **2 ways**

1. **Advection** of water masses

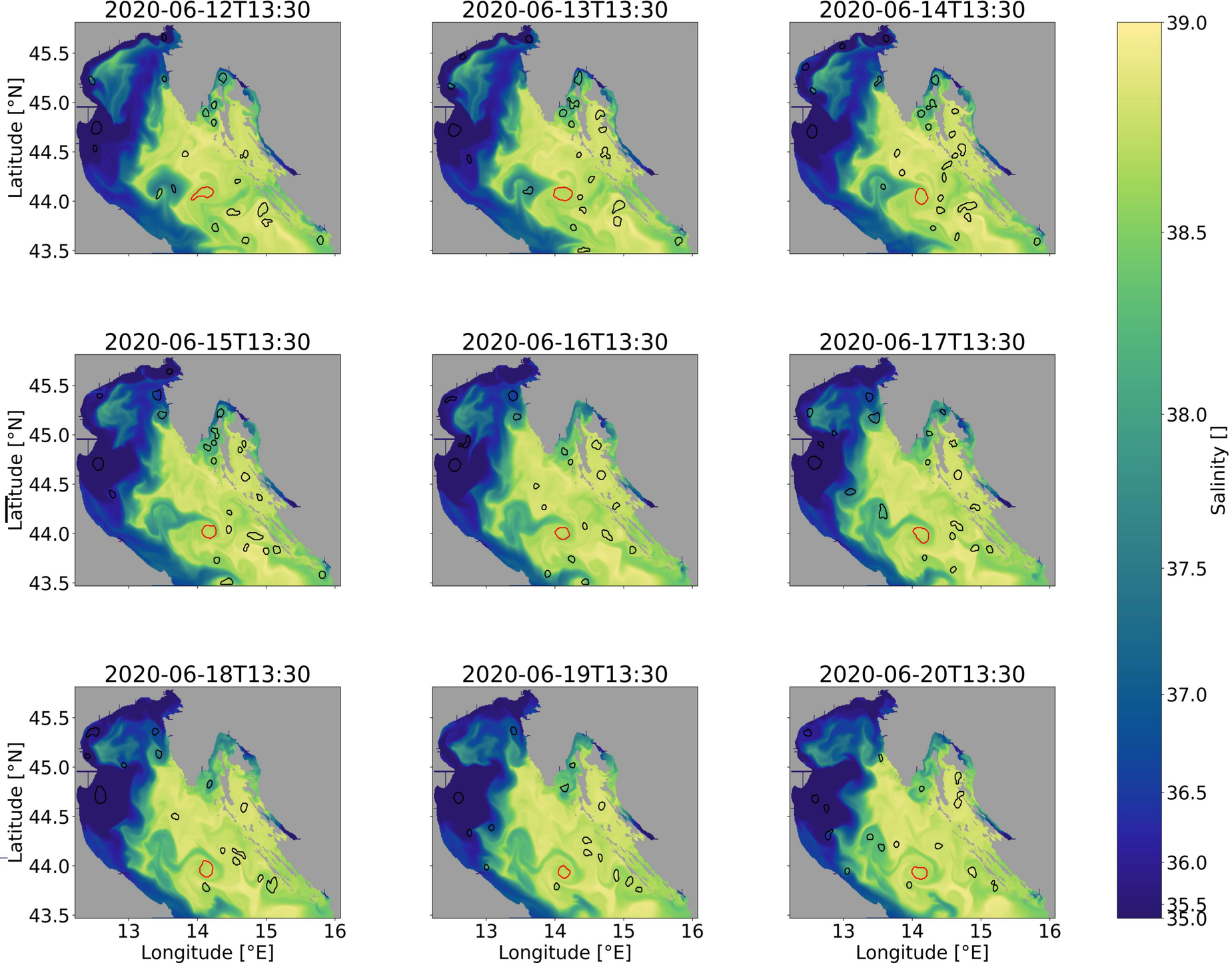


Mesoscale dynamics: Eddy field

Eddies contribute in **transport** of tracers (e.g. salinity) in **2 ways**

1. **Advection** of water masses
2. **Entrainment** of coastal fresh water

NAS = **small** domain ⇒ **entrainment > advection** (qualitative guess...)



Take home messages

High **resolution** is important, but is **not enough**: **mixing schemes** as relevant

Better resolving **vertical** dynamics:

- **TKE based schemes** (e.g. GGL) = good performance, even at coarser resolution ⇒ less expensive ⇒ **efficient** and **accurate** models

Effects on **mesoscale**:

- More stable **stratification** ⇒ more stable mesoscale circulation (**eddies**)
- Role of eddies in **transport** of tracers ⇒ improvement also for **biogeochemical** forecasts, **pollution** dispersal etc

Take home messages

High **resolution** important, but is **not enough**: **mixing schemes** as, if not more, relevant

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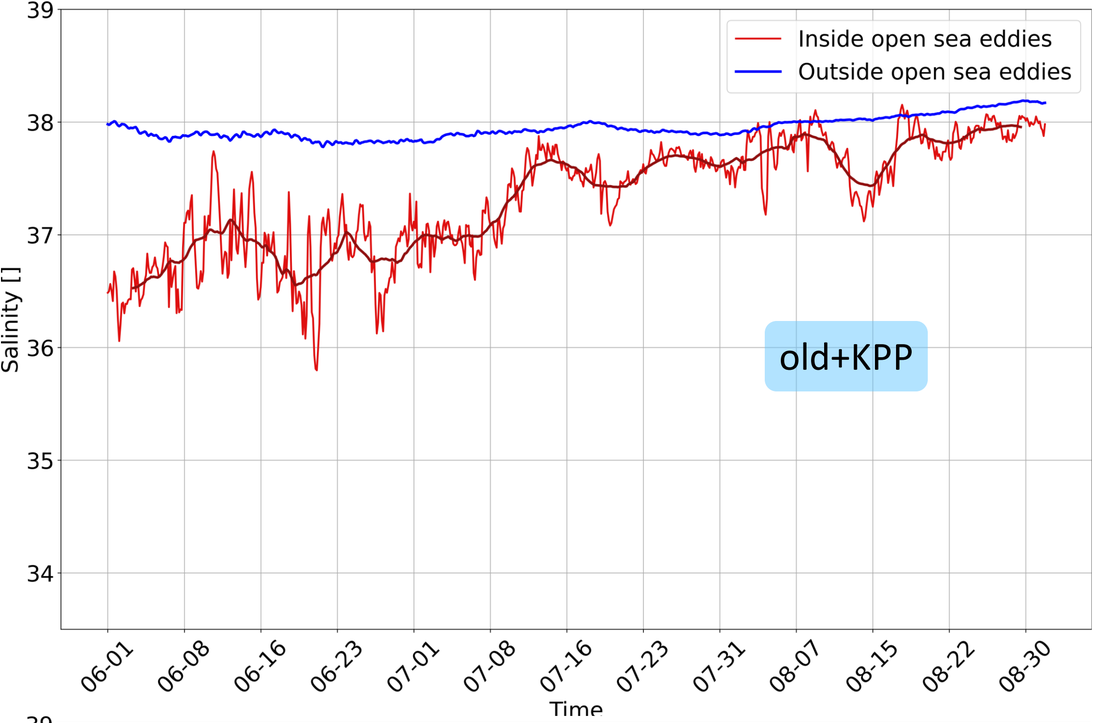
Thank you for your attention!

Additional material


Inside open sea eddies
Outside open sea eddies
old+KPP
Salinity []
Time
39
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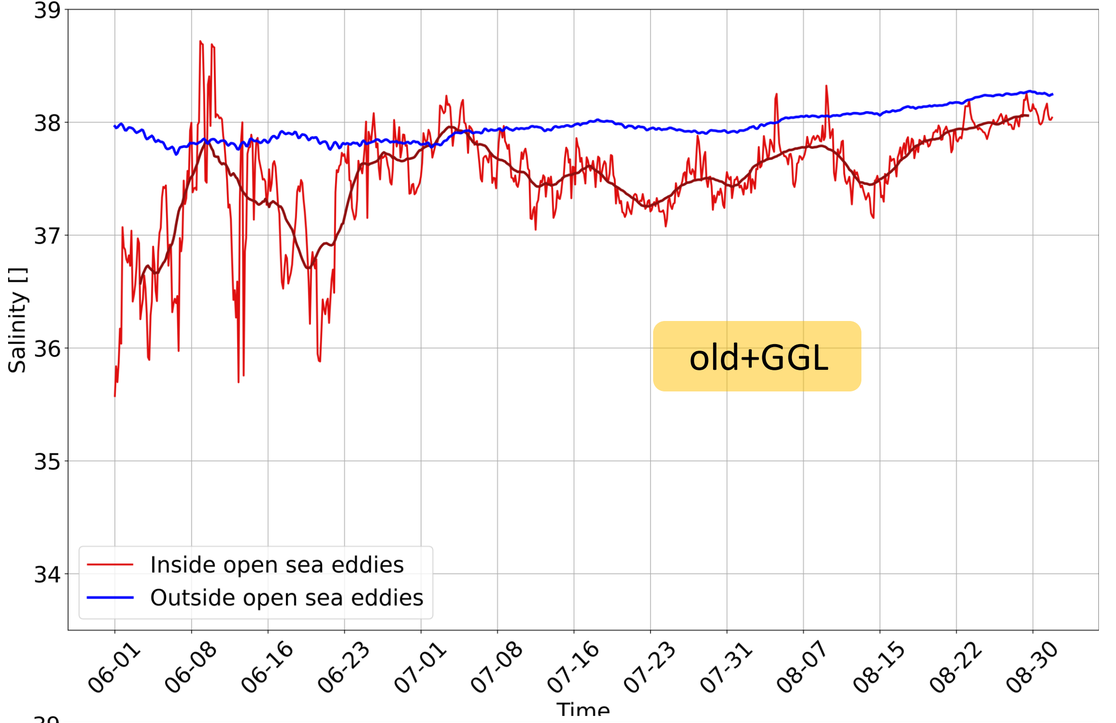
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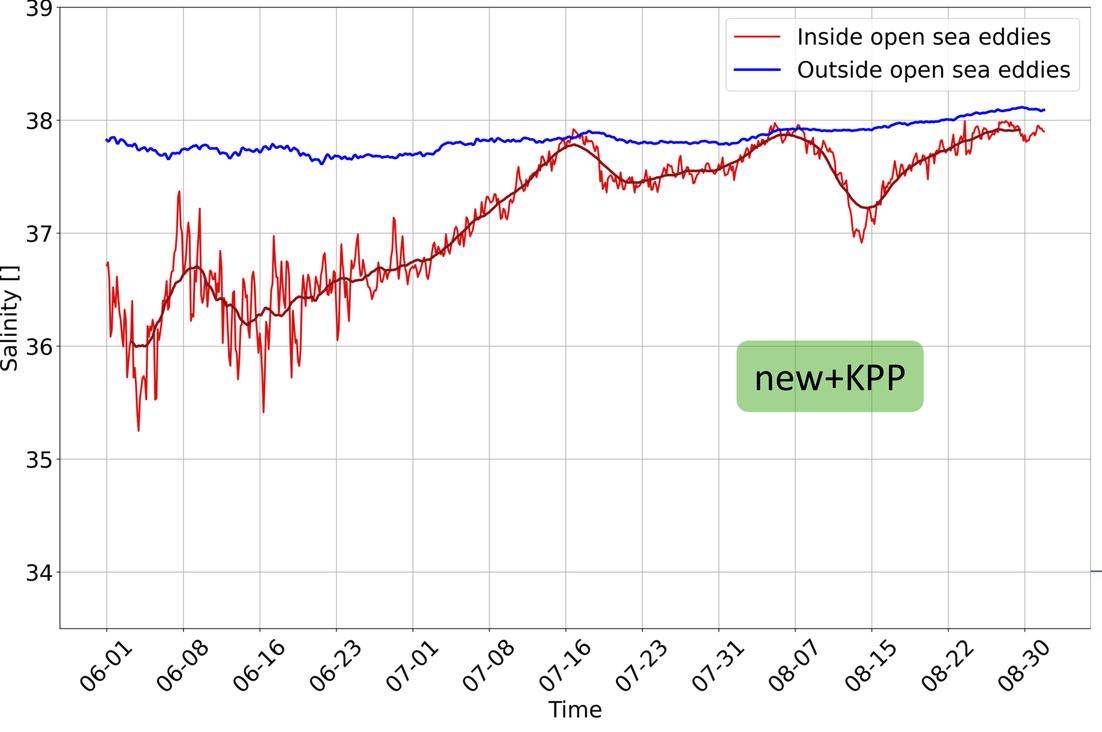
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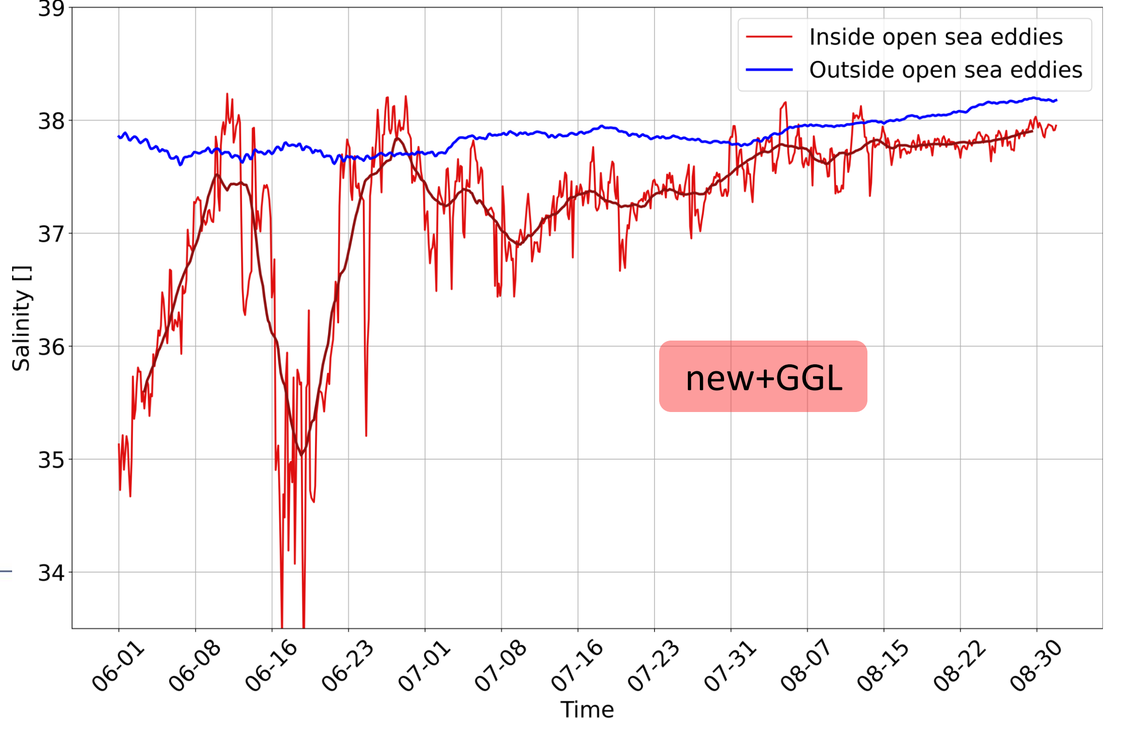
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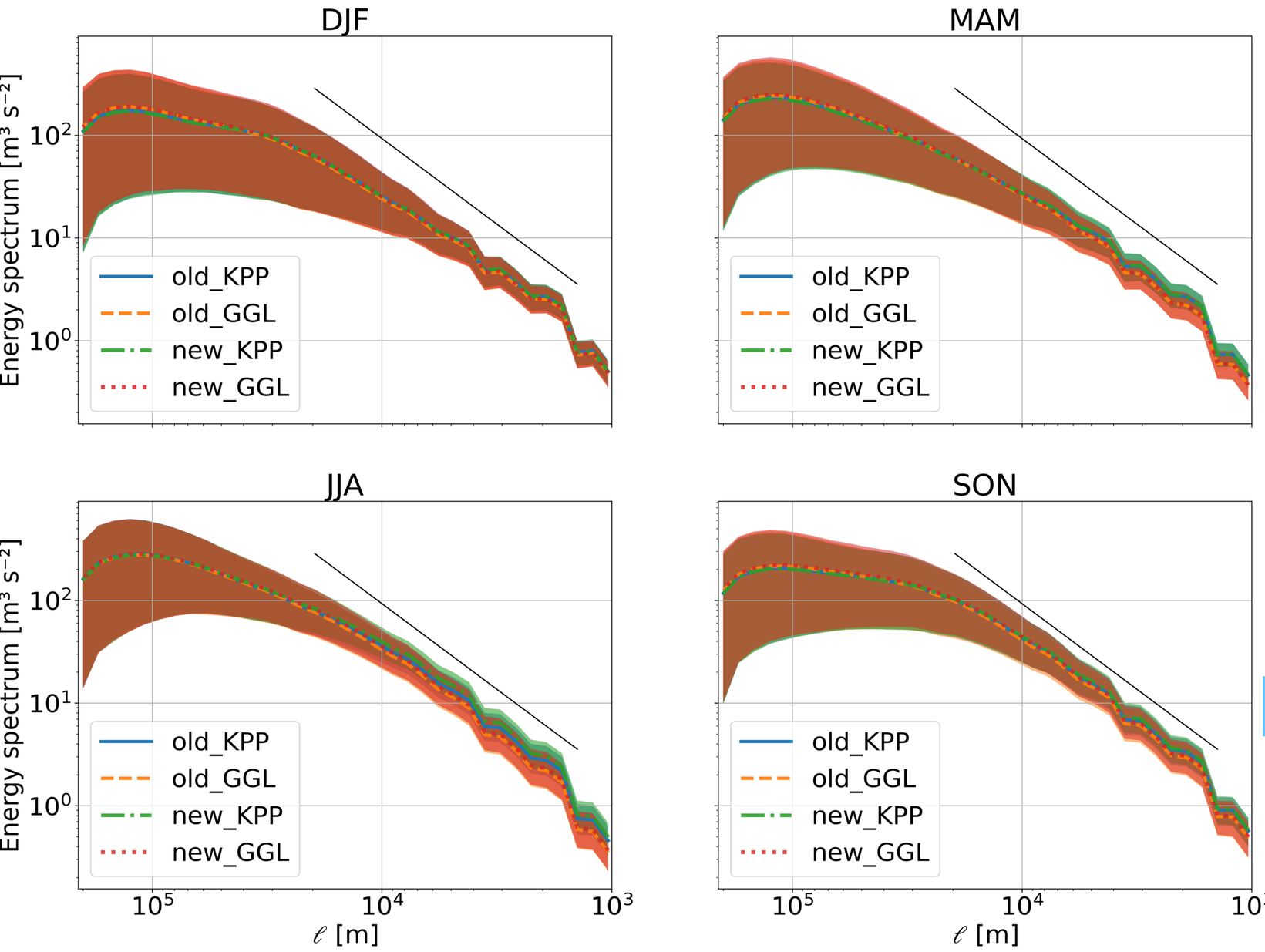
Mesoscale dynamics: Energy spectra



Contributions of different **length scales** to **kinetic energy**

GGL steeper in mesoscale range (summer)

new+GGL: closest to 5/3 ≃ 1.667 power law scaling

old+KPP	old+GGL	new+KPP	new+GGL
1.564	1.618	1.557	**1.632**