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Tracer Evolution in Multiscale Oceanic Flow Fields



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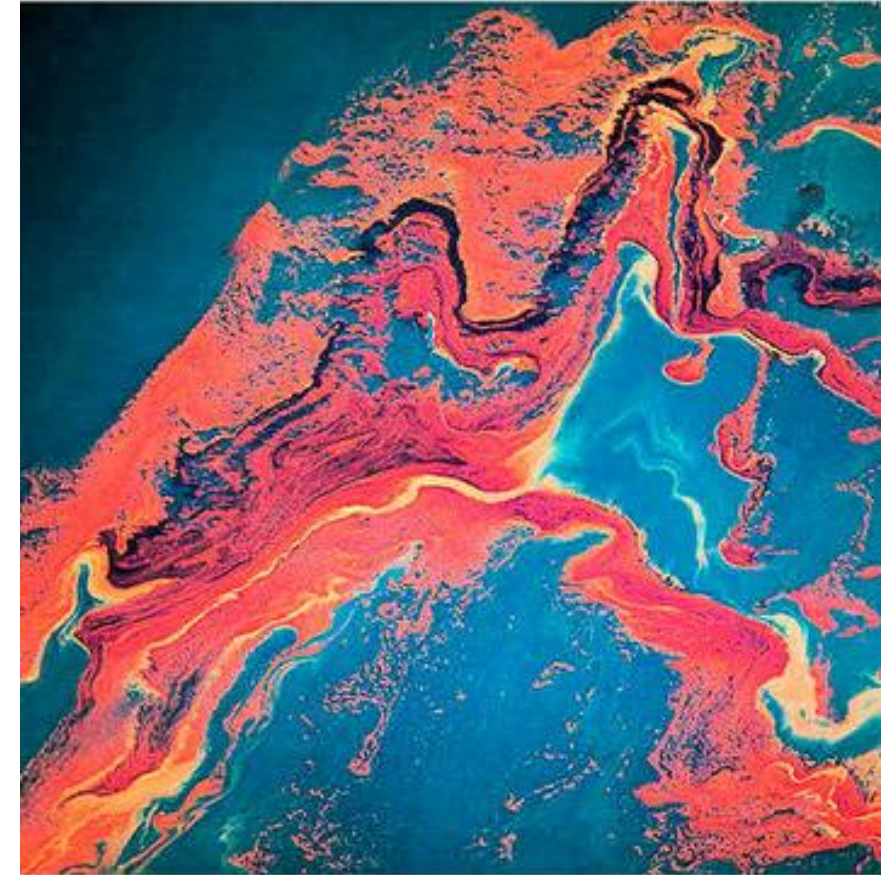
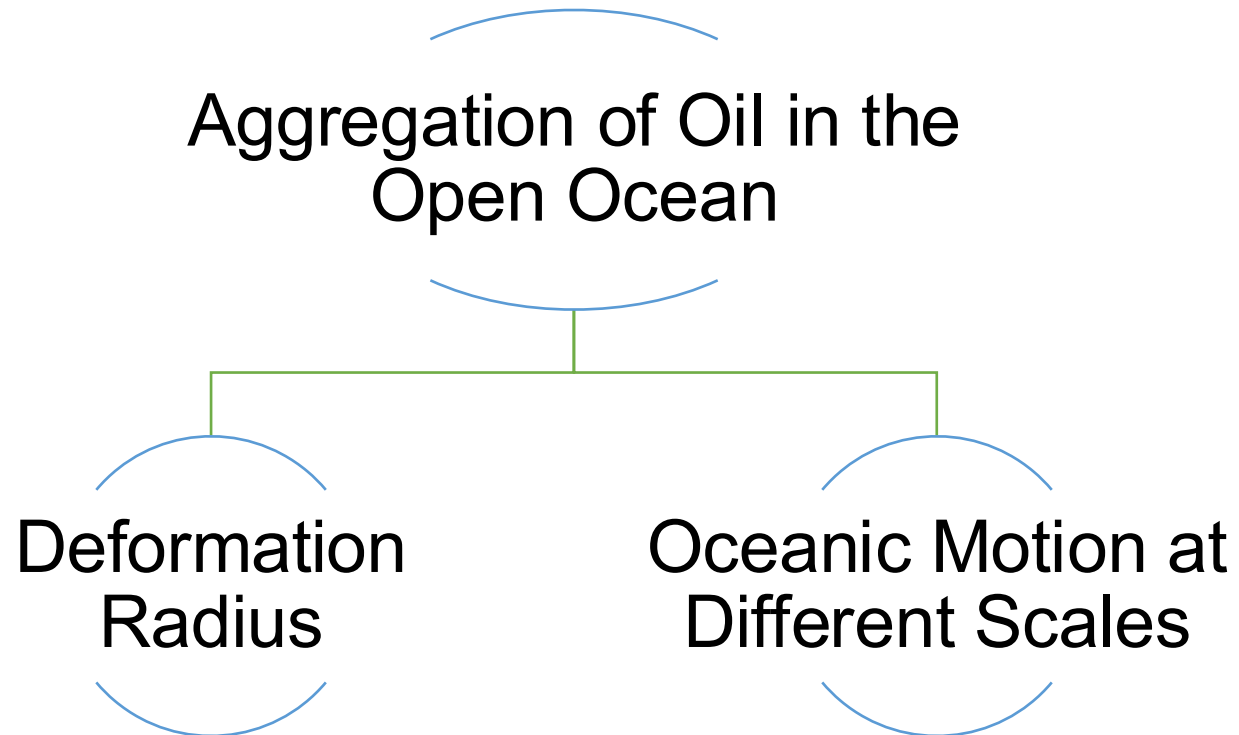


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2



Aim of the Study



Fingas, M.
Visual Appearance of Oil on the Sea.
J. Mar. Sci. Eng. **2021**, 9, 97.
<https://doi.org/10.3390/jmse9010097>

Methods

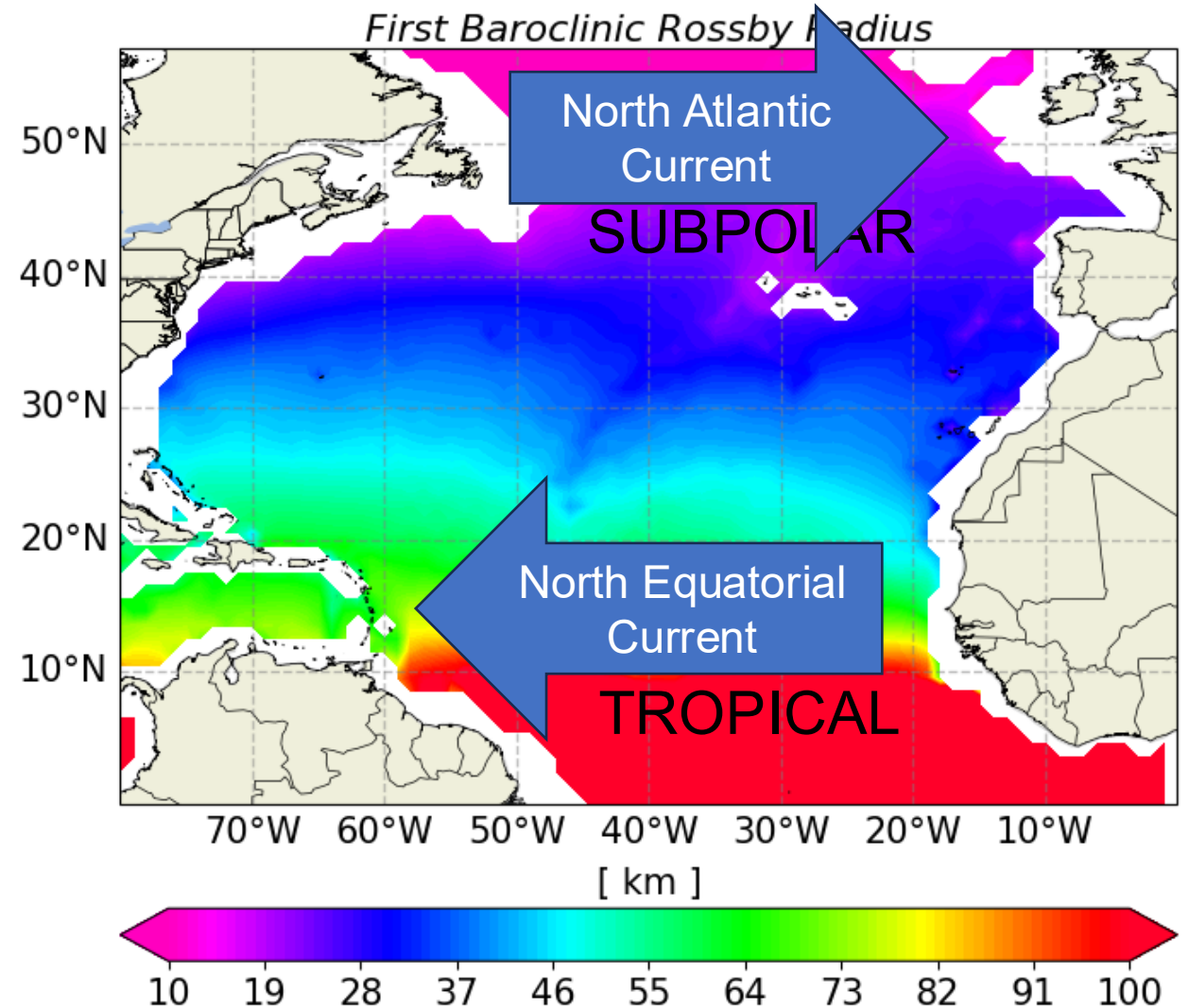
2 Regions with Different Deformation Radius (Subpolar and Tropical)

Ocean Dynamics Simulations at Different Resolution

Oil Spill Simulations

Statistical Analysis

Sepp Neves et al., *A General Methodology for Beached Oil Spill Hazard Mapping* (2020)



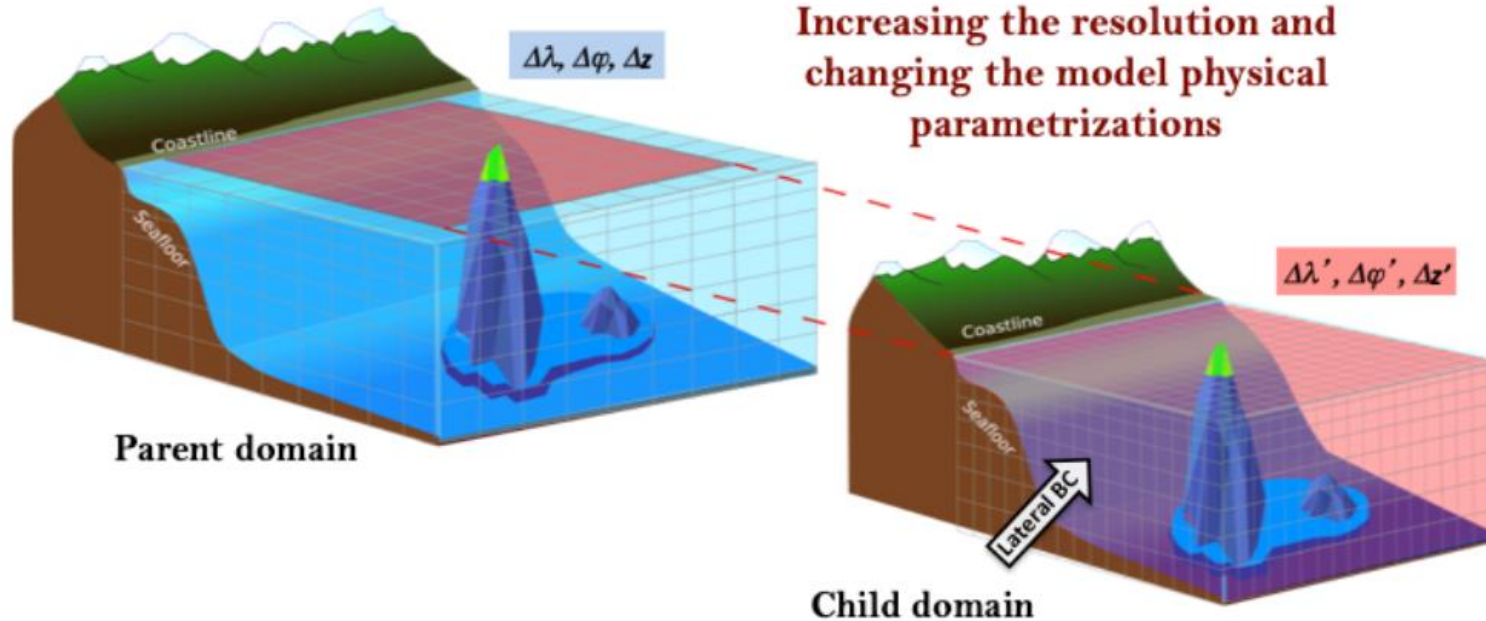
https://ceoas.oregonstate.edu/rossby_radius

Ocean Simulations - Dynamical Downscaling



<https://www.surf-platform.org>

Increasing the resolution and
changing the model physical
parametrizations



Jan-Jun 2025

• NEMO-OCEAN v5.0.1

9 km

CMEMS12*



3 km

NEST36



1 km

NEST108

- Representation of New Dynamical Regimes
- Sharper Strain Rate Field Controlling Tracer Filamentation

* Copernicus Marine Service

<https://doi.org/10.48670/moi-00016>

Oil Spill Simulations (MEDSLIK-II)

<https://www.medslk-ii.org>

Jan-Jun 2025

- 1 Simulation Every 5 Days
- Simulation Length: 10 Days
- 10k Tons Released Continuously for 120 hrs

Beached Oil

- Virtual Circular Coastlines
 - 50 km and 100 km
 - Segments Length = Oil Tracer Grid Step

Experimental Design

Resolution →	~9 km CMEMS-GLO12	~3 km NEST36	~1 km NEST108
TROPICAL $R_d \approx 100-150$ km	~30 runs 10 d each	~30 runs 10 d each	~30 runs 10 d each
SUBPOLAR $R_d \approx 10-20$ km	~30 runs 10 d each	~30 runs 10 d each	~30 runs 10 d each

Same MEDSLIK-II configuration in every cell — only the driving ocean field changes.



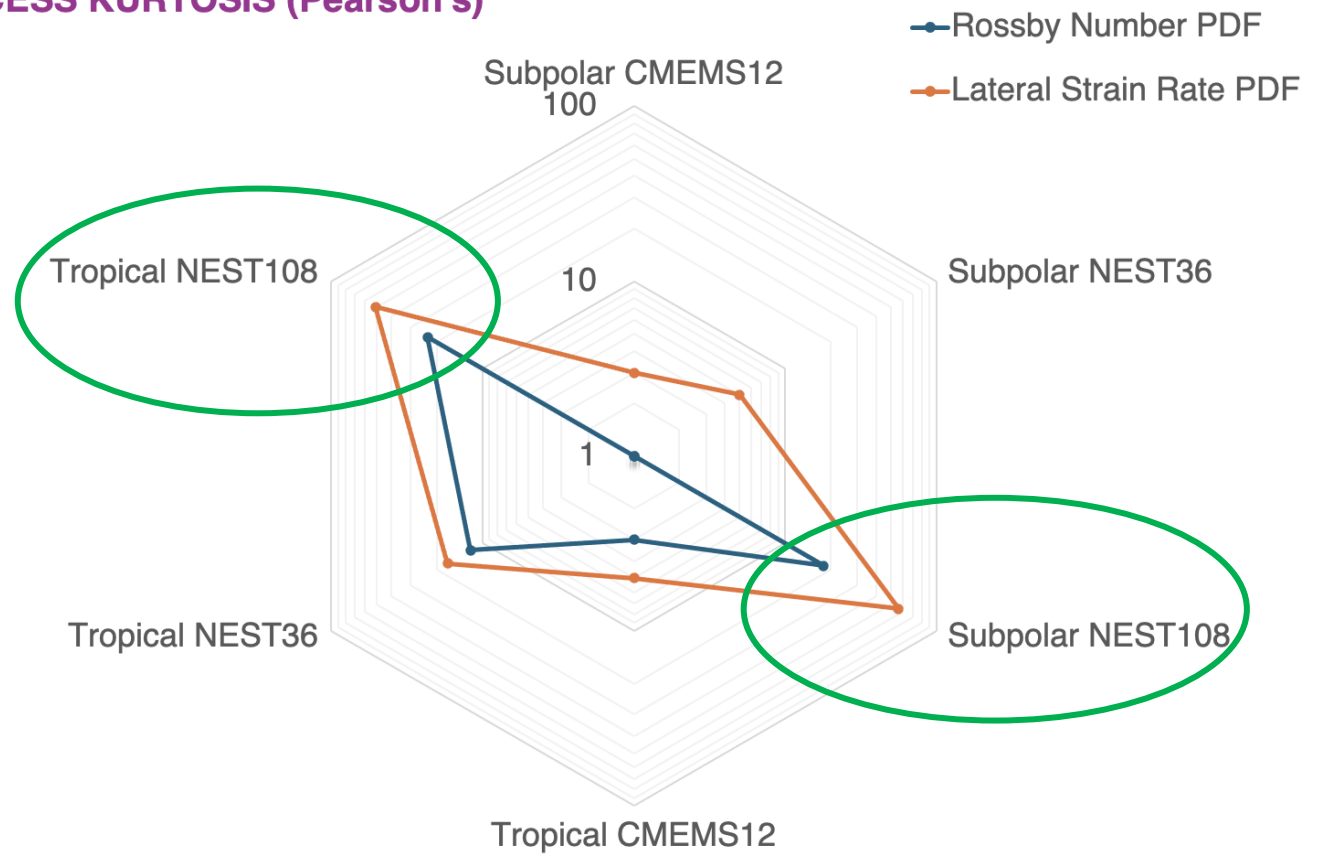
Resolved Frontogenesis — Heavier-Tailed Strain Statistics

Higher Resolution

- *Fatter Tails in the Surface Strain Rate* PDF*
- *Submesoscale Fronts Captured*

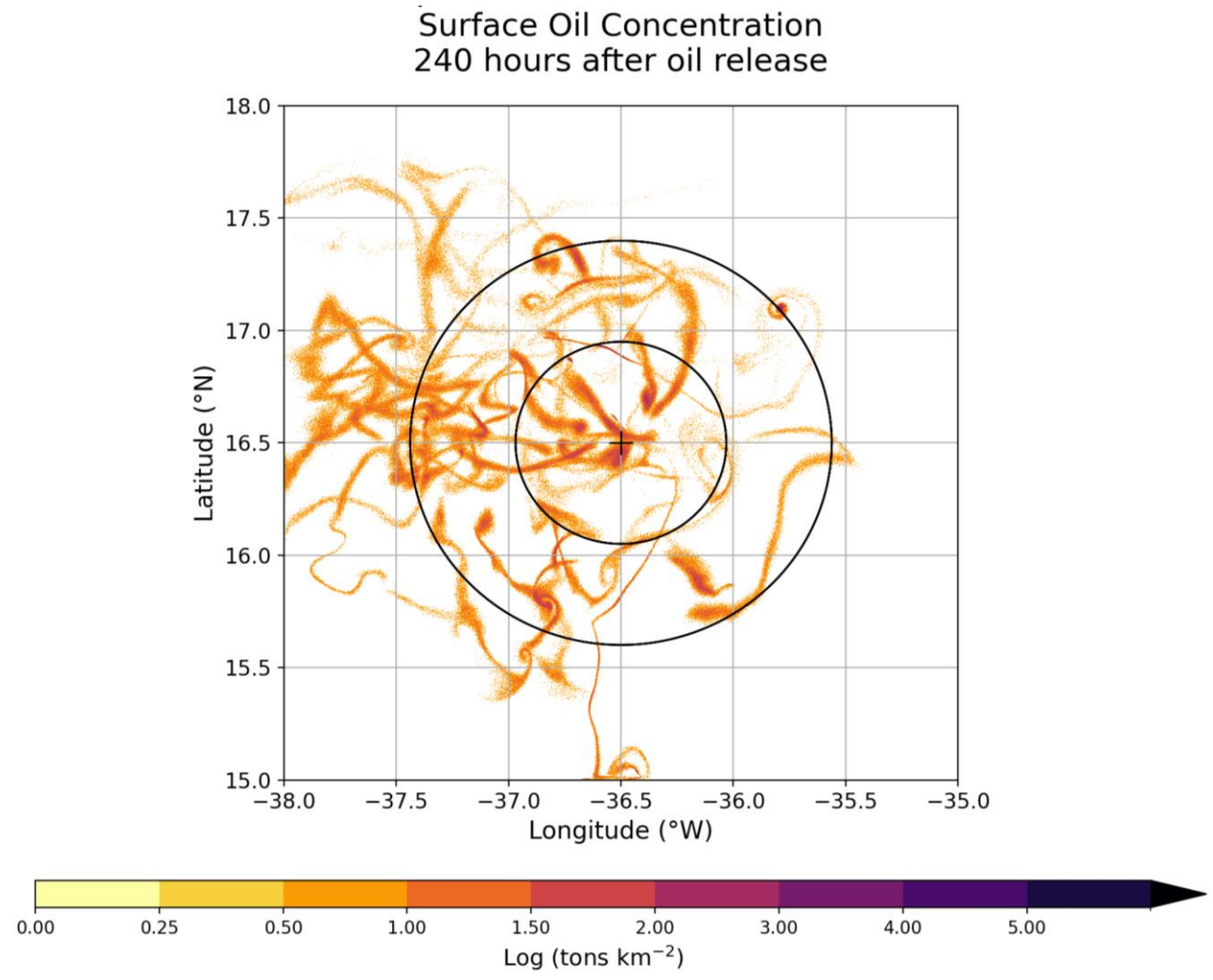
* Thomas et al., *Submesoscale Processes and Dynamics* (2008)

EXCESS KURTOSIS (Pearson's)



Surface Oil Concentration Evolution

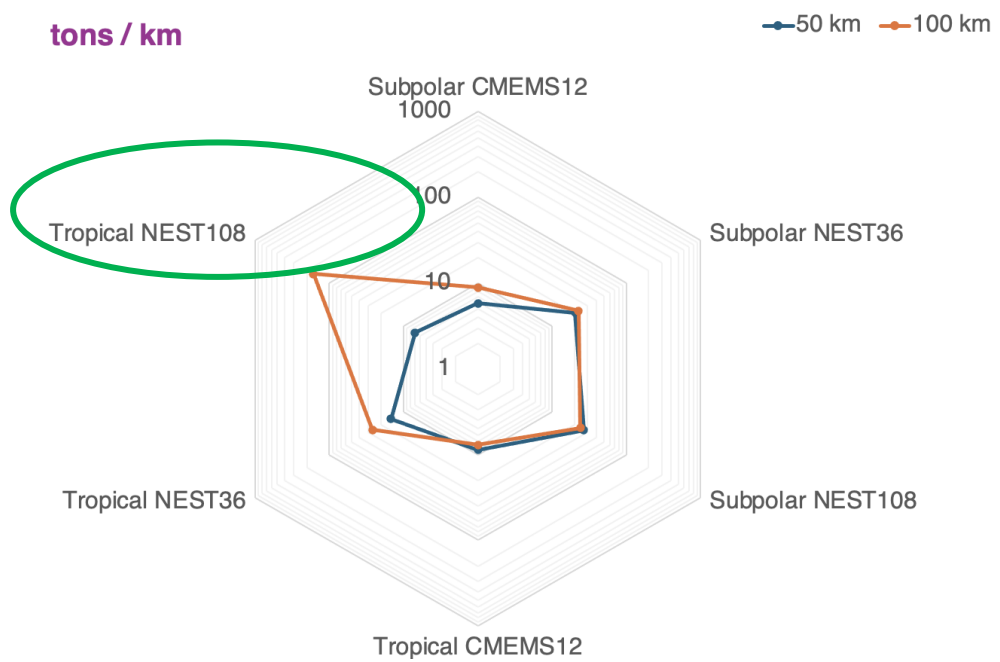
- Initially Compact Release
- Evolution into Elongated Filaments, Patchy Structures
- **After One Week**, Strong Filamentation and Spatial Spreading Around the Release Area



Beaching Footprint Concentrates with Resolution

↑ Submesoscale Frontogenesis and ↑ Deformation Radius
 → Significant ↑ in Oil Aggregation with ↑ Distance from the Oil Source

EXCESS KURTOSIS (Pearson's)



Coastline Impacted More Intensively by Oil with Increasing Resolution

	SUBPOLAR	TROPICAL
	% *	% *
50 km	50	50
100 km	50	70

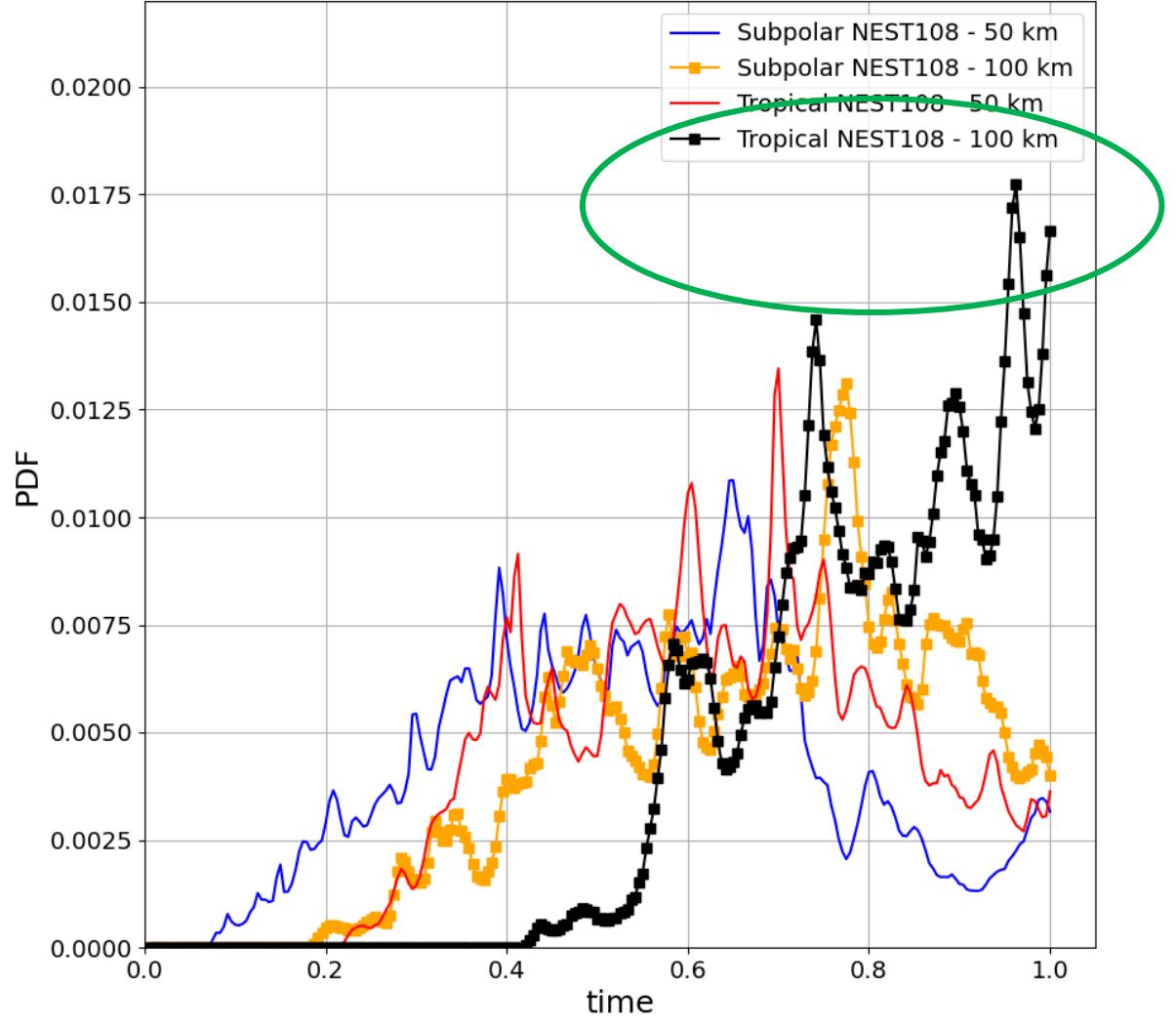
* Percentage of Segments Impacted both at Low and High Resolution

Transit-Time Statistics — Distance and Time Compound the Resolution Effect



- ↑ Deformation Radius
- ↑ Distance from the Oil Source
- ↑ Transit-Time
- **Particles Have More Time to Aggregate**

First-Passage Time Across the Virtual Coastline



Conclusion

How Do Pollutants Aggregate in the Open Ocean?

Ocean Dynamics and Oil Spill Simulations

Regions with Different Deformation Radius

Different Resolutions

↑ Submesoscale Frontogenesis and ↑ Deformation Radius

Significative ↑ in Oil Aggregation with ↑ Distance from the Oil Source



Thank You!

Benfenati, F. M., Trotta, F., and Pinardi, N.
Tracer Evolution in Multiscale Oceanic Flow Fields,
EGU General Assembly 2026,
Vienna, Austria, 3–8 May 2026, EGU26-10204,
<https://doi.org/10.5194/egusphere-egu26-10204>, 2026.