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Copernicus for MSFD in coastal waters: potential uses and future challenges

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Danish Meteorological Insitute

The Copernicus for Water Management workshop, Brussels, 29 May 2018

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MSFD for Good Environment Status

Good Environment Status means

- **D1.** Biodiversity is maintained
- **D2.** Non-indigenous species do not adversely alter the ecosystem
- **D3.** The population of commercial fish species is healthy
- **D4.** Elements of food webs ensure long-term abundance and reproduction
- **D5. Eutrophication** is minimised
- **D6.** The **sea floor integrity** ensures functioning of the ecosystem
- **D7.** Permanent **alteration of hydrographical conditions** does not adversely affect the ecosystem
- **D8.** Concentrations of **contaminants** give no effects
- **D9.** Contaminants in seafood are below safe levels
- **D10. Marine litter does** not cause harm
- **D11.** Introduction of energy (including **underwater noise**) does not adversely affect the ecosystem

Coastal waters (a few nm from the shore)

- Highly dynamic area
- Most of the current GES assessment use only low resolution in-situ data
- High resolution (in the **order of 100m**) physical-BGC-wave-SPM-pollutant-noise data are needed, to address directly **D5-D8 & D10-D11**, also indirectly **D1-D4 and D9.**

Setting the scene: integrated approach

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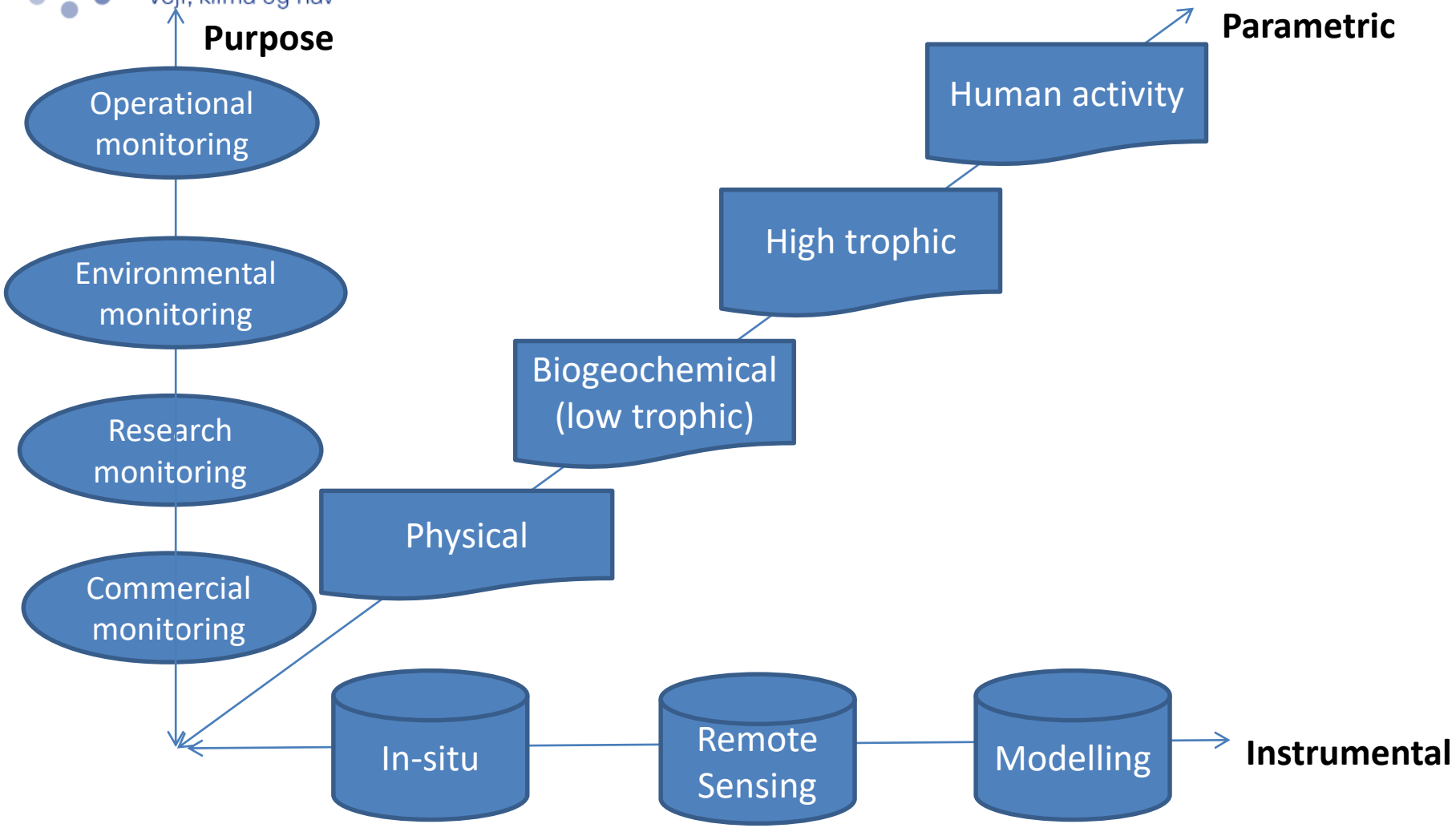

Integration in BOOS: breaking institutional and community barriers in ocean observing (OceanOBS19)

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Platforms	Parameters	Spatiotemporal resolution	Amount in European Seas	Usefulness in Coastal MGT
Ferrybox	T,S, DO, pH, Chl-a, Turbidity, diss.CO2, N, S, P, Ammonia, Yellow Substance etc.	300m, 1-7 days	49 lines (in operation)	Eutro.Assess., tested
HF Radar	Current speed, direction	500m-6km, hourly	142 (72 in HFR TT)	Hydrog.Change in R&D
Tidal gauge	Water level, SST	Single location, 5-60minutes	>600	Hydrog.Change Used
River	Water level, river flow, river temperature		More data to be collected	Useful, to be developed
Bathymetry	Water depth	50-250m		Used
Plastic litter	Micro and macroplastic litter sources, concentration			To be developed
Sentinel-2 MSI	**Turbidity, SPM, Coastal chl-a**	**10m, 5days**		**Eutro.Assess, tested, in R&D**
Sentinel-3 OLCI	Turbidity, SPM, Coastal chl-a	300m, 5days		Eutro.Assess, in R&D
CMEMS TACS	SST, winds, ocean color, waves, Sea surface hight, sea ice	1-25km, >1day	6 TACs, satellite L3/L4 products	Too coarse resolution
CMEMS MFCs	T/S, waves, sea level, sea ice, currents, nutrients, DO, chl-a, Ammonia, C, pH etc.	1-7km, 1h-1day	6 MFCs, forecast Reanalysis	boundary conditions
Hydrological	River discharge of fresh water, nutrients	Per catchment, hourly	Forecast, hindcast	Used as input data

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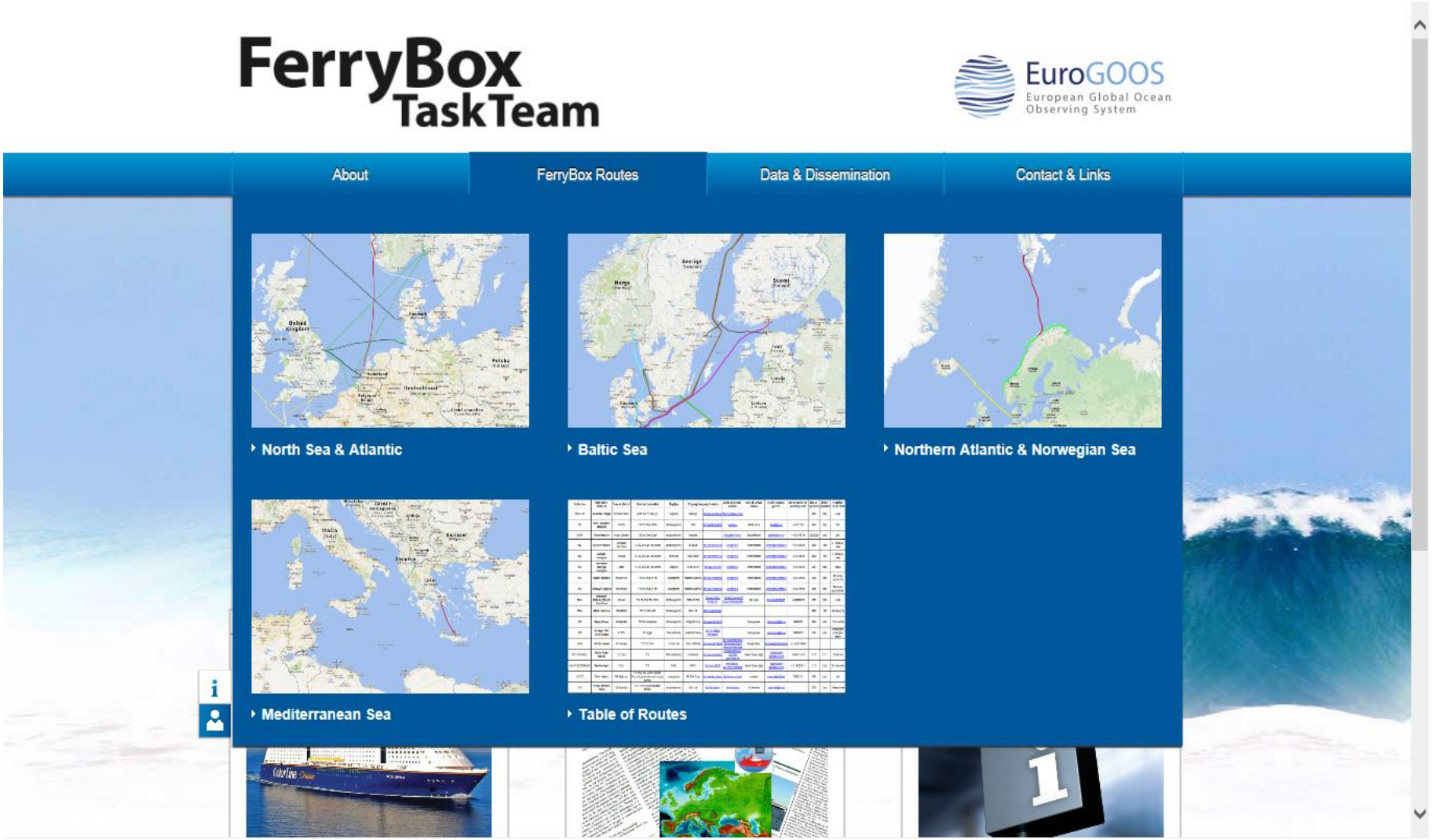
Operational ferrybox in Europe



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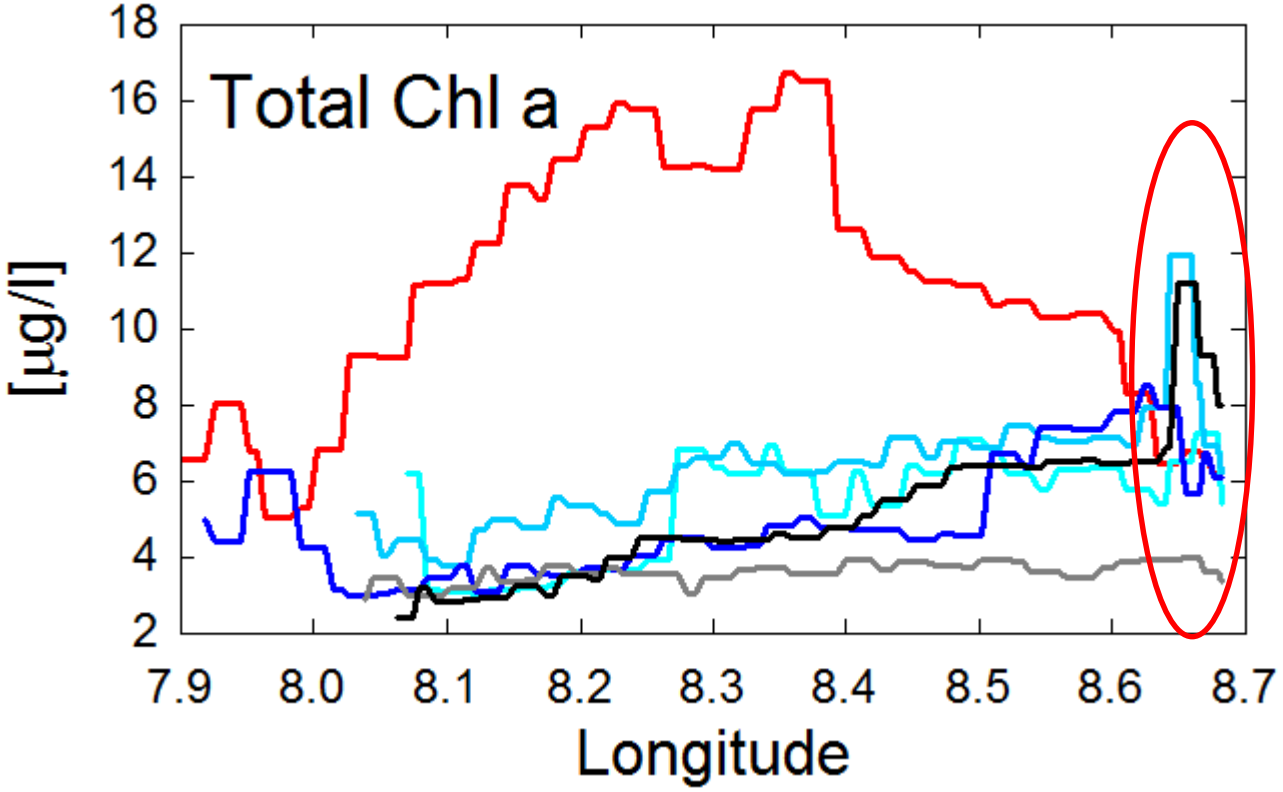
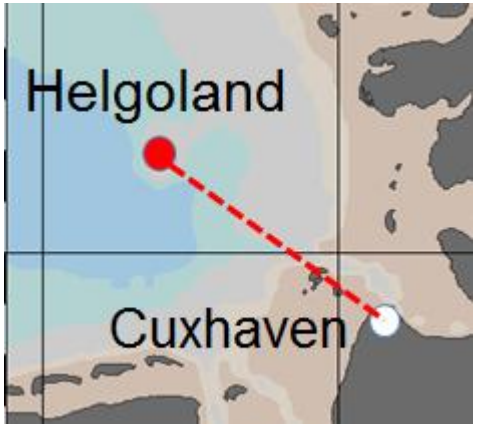
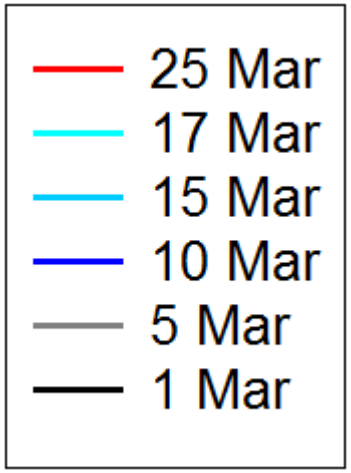
Ferrybox for monitoring coastal gradient, flood events etc.







2016

Courtesy: Scharfe et al. 2016

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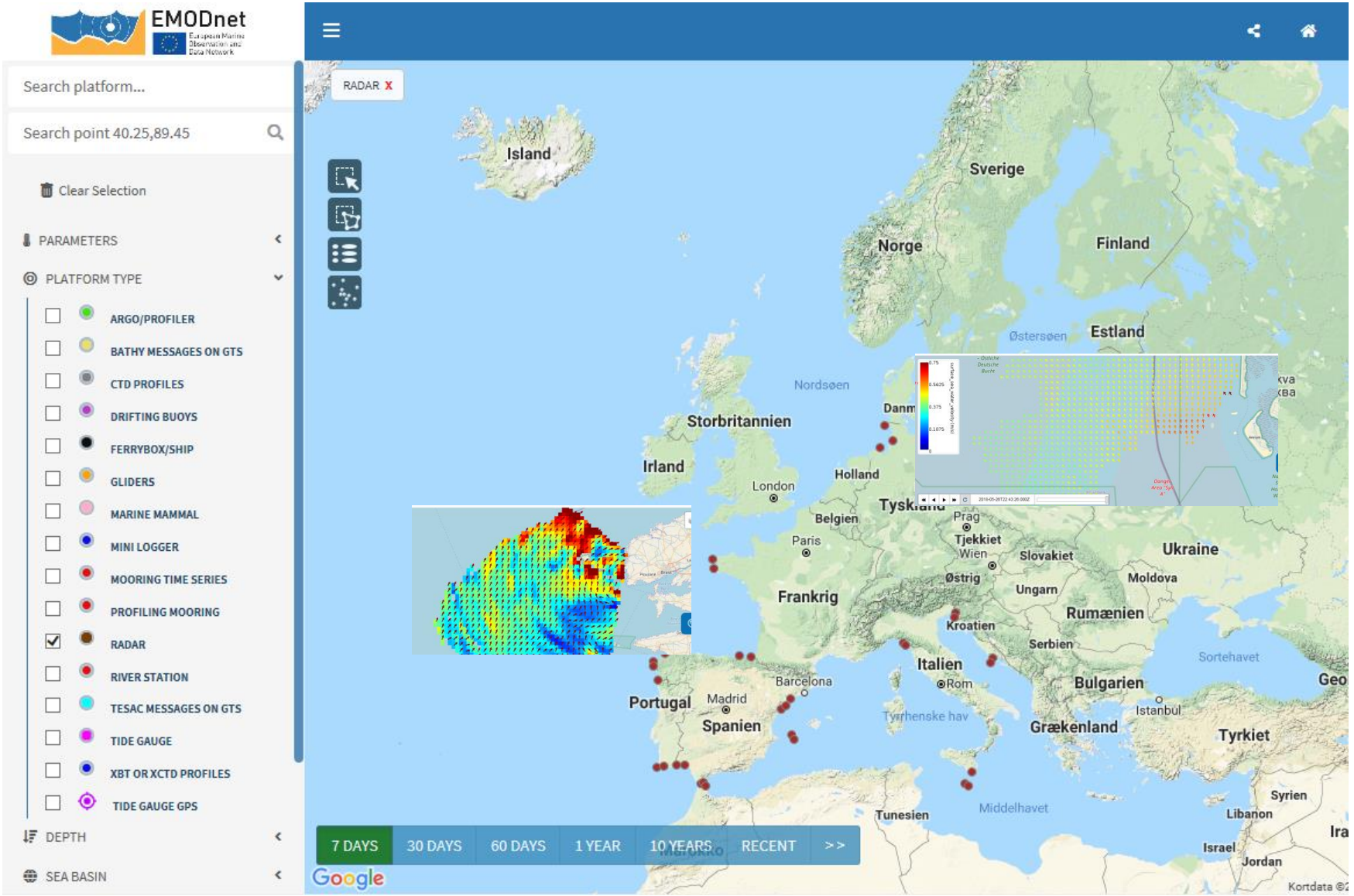
HF radar for monitoring coastal currents



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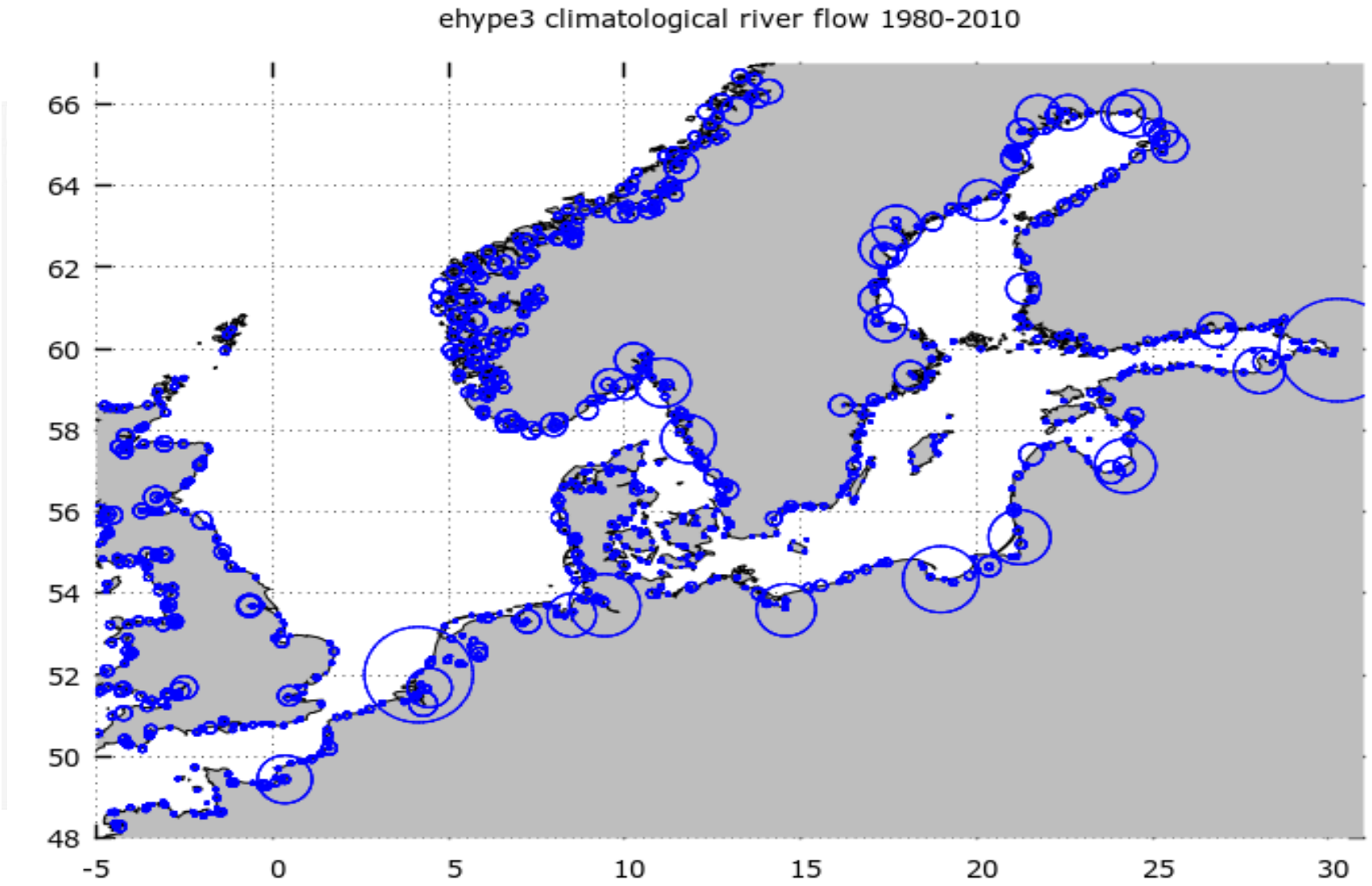
River data (Observation and model)



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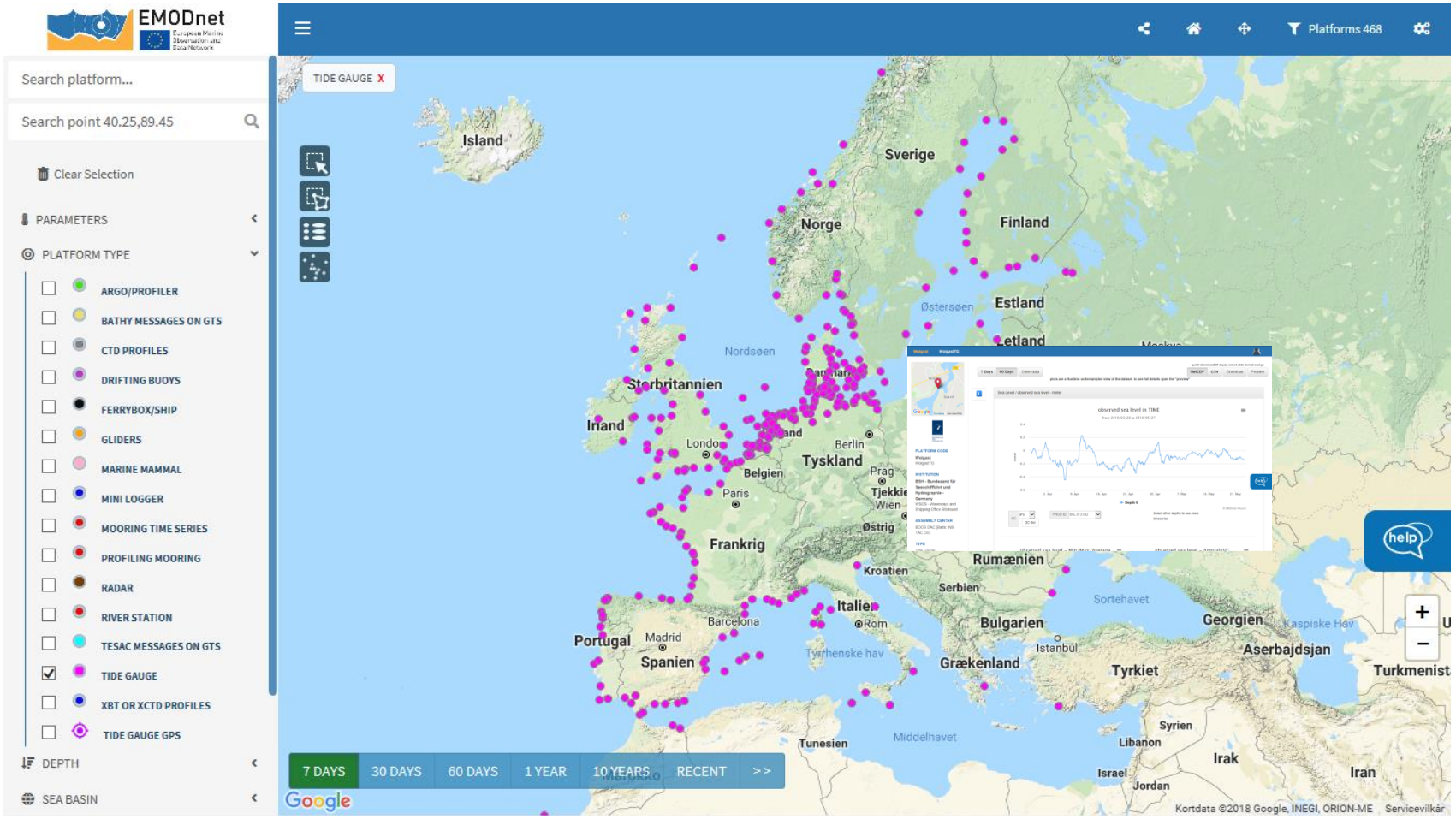
European tidal gauge observations



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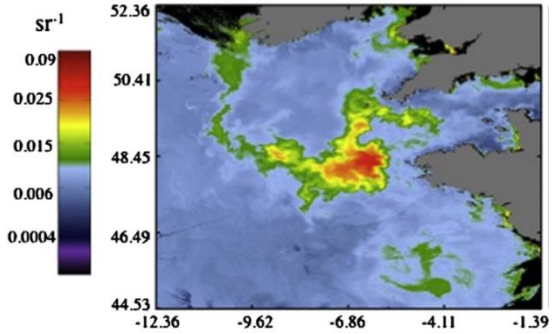
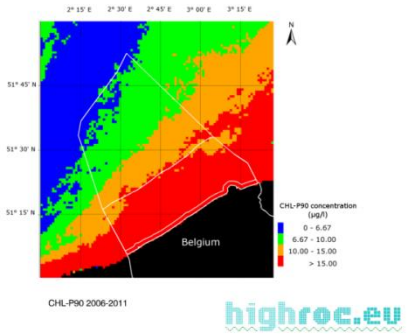
Applications of Sentinel-2 and 3 in coastal waters (Lavigne H. et al. 2016, RBINS)

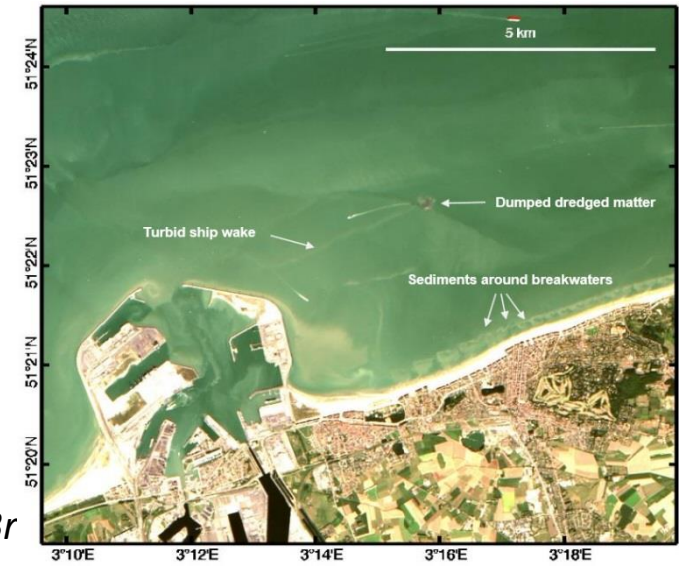
Aquatics Applications – Spectral resolution

	Application	User	Parameter
App1	Coastal water quality (EU MSFD/WFD reporting)	National govt	CHL – Turbidity (TUR)
App2	Harmful Algae Blooms near real-time alert	National govt Fisheries Aquaculture	CHL, phytoplankton type (Harmful algae bloom)
App3	Carbon cycle modelling and Ocean acidification	Ecosystem modelers	CHL, PAR, Kd, euphotic depth
App4	Marine Science support	Marine scientists (esp. biology)	CHL
App5	Coastline/Bathymetry change, dredging/dumping	Sediment transport modelers	SPM, TUR for model val/initial
App6	Offshore construction (environmental impact)	Govt + Offshore industry	SPM, TUR
App7	Diving ops; Detection of subs, mines; marine animal vision	Diving industry Military, Biologists	Underwater visibility

- OC remote sensing is an essential tool to observe coastal regions.
- With high spatial resolution sensors (S2, L8) small scale features are visible.
- Sentinel-2/MSI and Sentinel-3/OLCI data represent an important contribution to ocean colour.







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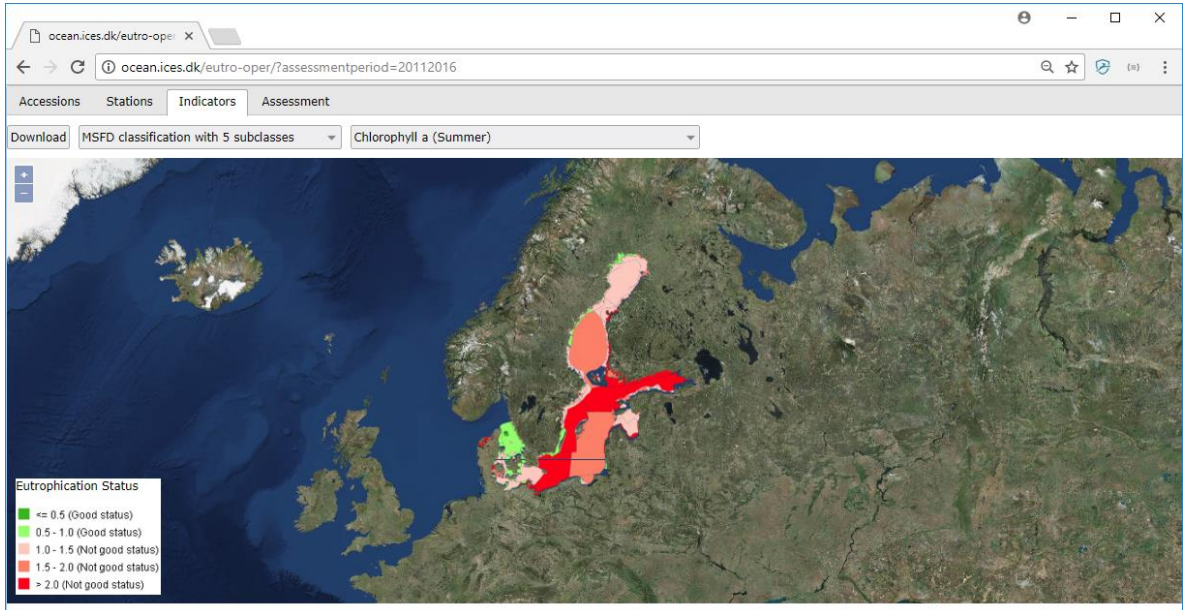
Chl-*a* (Summer) indicator including in-situ, earth observation chla data (EO) and Ferrybox data



Assessment Unit		Period	ES	STD	N	ET	ER	ES-SCORE	ET-SCORE	I-SCORE
ID	Description									
SEA-001	Opensea Kattegat	20112016	0.94	0.18	111320	1.50	0.63	100	0	50
SEA-002	Opensea Great Belt	20112016	2.00	0.19	5084	1.70	1.18	100	50	75
SEA-003	Opensea The Sound	20112016	1.26	0.27	411	1.20	1.05	100	50	75
SEA-004	Opensea Kiel Bay	20112016	2.27	0.24	132	2.00	1.13	100	50	75
SEA-005	Opensea Bay of Mecklenburg	20112016	2.21	0.45	218	1.80	1.23	100	50	75
SEA-006	Opensea Arkona Basin	20112016	2.64	0.44	196	1.80	1.47	100	50	75
SEA-007	Opensea Bornholm Basin	20112016	3.87	0.92	532442	1.80	2.15	100	50	75
SEA-008	Opensea Gulf of Gdansk	20112016	3.49	0.87	7435	2.20	1.59	100	50	75
SEA-009	Opensea Eastern Gotland Basin	20112016	2.94	0.44	1673...	1.90	1.55	100	50	75
SEA-010	Opensea Western Gotland Basin	20112016	2.64	0.30	301766	1.20	2.20	100	50	75

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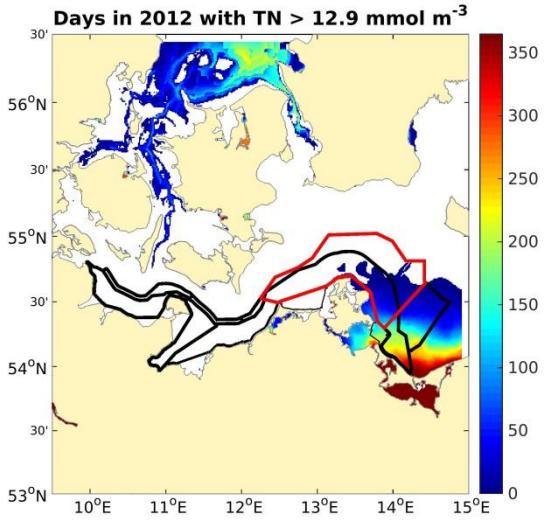
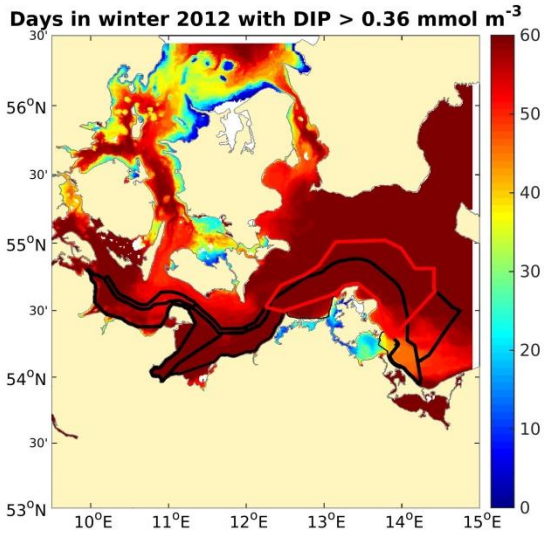
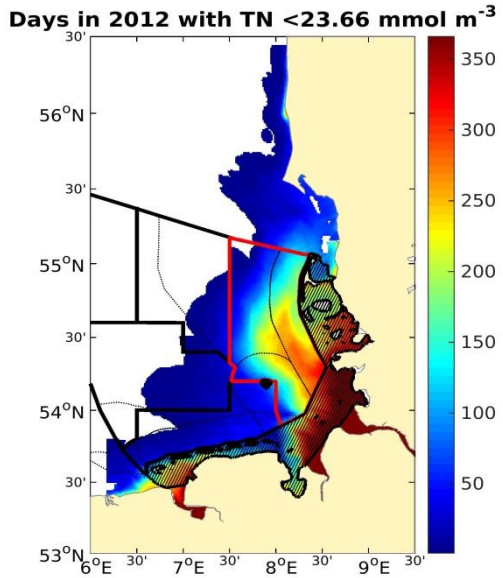
Tailored products: CMEMS Ocean Monitoring Index and national products

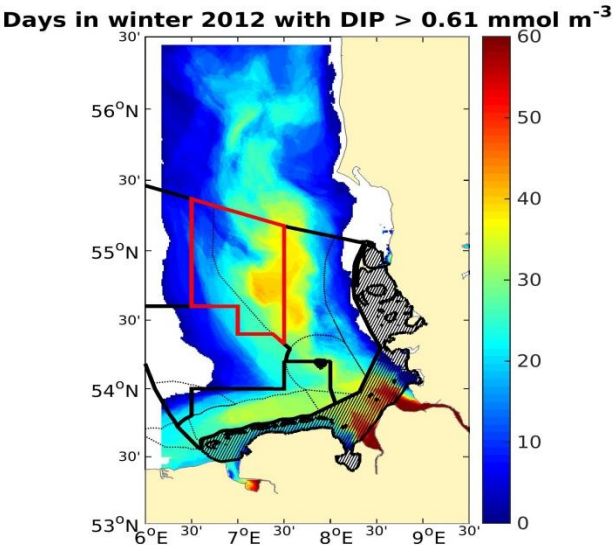


Example:
Days of high TN and DIP in Danish Straits from CMEMS





Example:
Days of high TN & DIP in German Bight from CMEMS



Courtesy: Fabian Schwichtenberg, BSH

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Examples of using modelling tools in coastal-estuary continuum

Platform	Parameters	Resolution, grid	Test area	
HBM	Physical	Fine to 185m, two-way nested	Limfjørd, Inner Danish waters	Storm surge, resuspension
HBM	Physical	22-60m, two-way nested	12 Port-lake systems in Latvia	Storm surge, river plume
HBM	Physical	90m, two-way nested	Elbe river	Storm surge, flooding, river plume
HBM	Physical	500m, two-way nested	Gulf of Finland	Estuary circulation, oil drift, plastic drift
Flexsem	Biogeochemical	Fine to 185m, unstructured grid	Limfjørd, inner Danish waters	Resuspension, Aquaculture assess.

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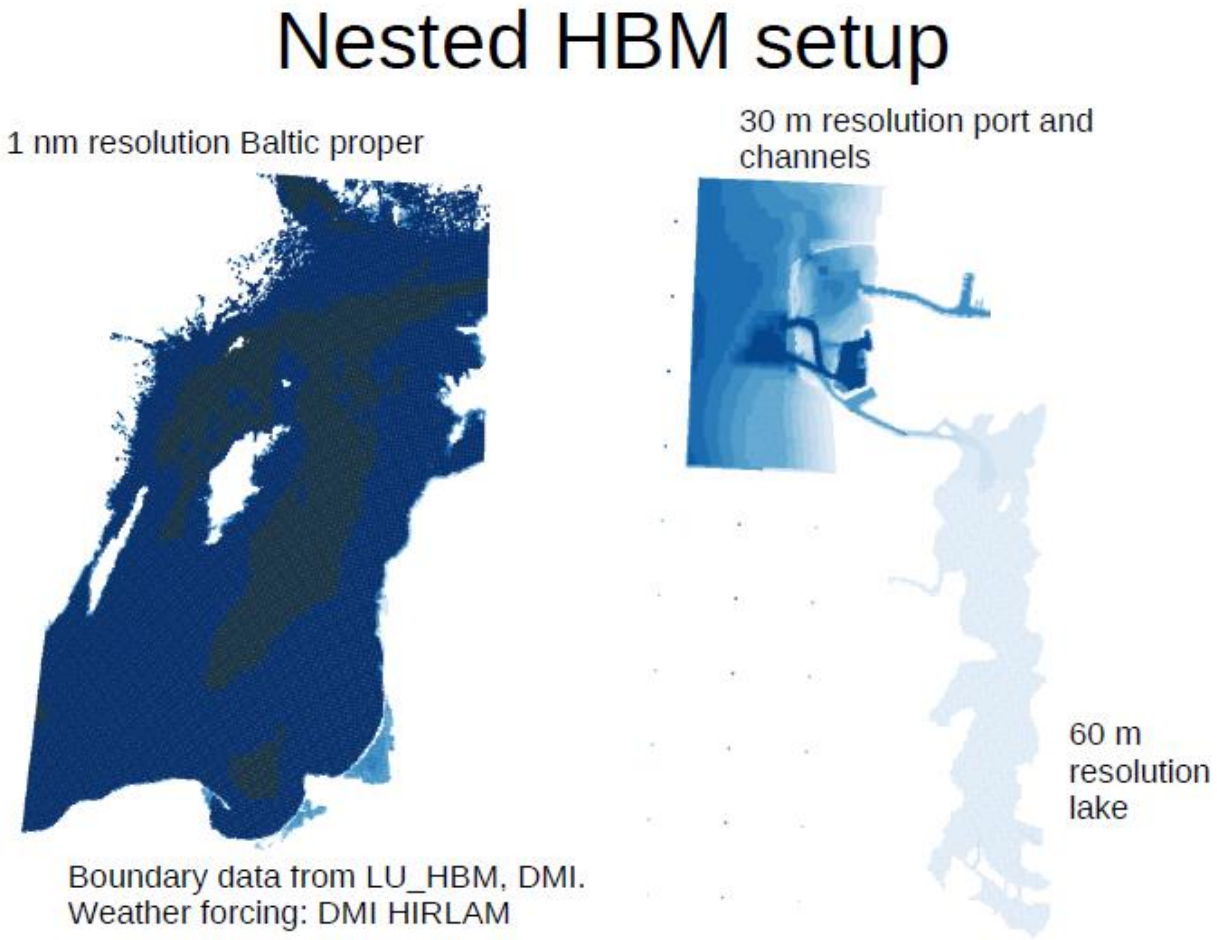
Developing forecasting capacity in coastal-estuary continuum: Liepaja port-lake system in Lativa

(Courtesy: Frishfelds et al. 2018)



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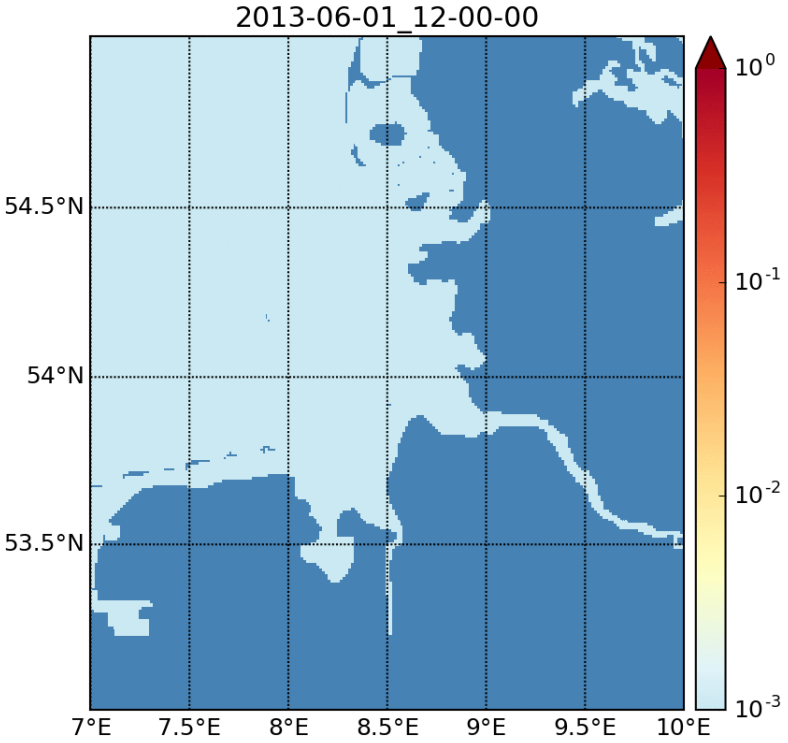
Developing forecast capacity for plastic litter drift: CLAIM project (DMI, MSI, DTU, HCMR)

Micro Plastics (≤5mm), DMI	Macro Plastics (>5mm), DTU-Aqua
Eulerian Passive tracers	Lagrangian Particles
Large number of particles with well defined properties (sinking, etc.)	Limited number of particles that might change their properties (degradation) and are allowed to interact with each other.
Modelling concentrations	Modelling particle trajectories
HBM	Individual Based model (IBM)
Key processes: • Small scale eddies & river plumes • On-shore or long-shore transport caused by waves • Biofouling • Resuspension • Vertical mixing	**Key processes**: • Direct wind forcing • Small scale eddies & river plumes • On-shore or long-shore transport caused by waves • Beaching (landing & re-activating)



Eulerian drifter experiment for the river Elbe. Courtesy Thorger Brüning (BSH)

Observations needed: Plastic litter database

Monitoring needed: Ferrybox monitoring, field experiments

Using coupled ocean-BGC model HBM-Flexsem for resuspension study in Limfjød

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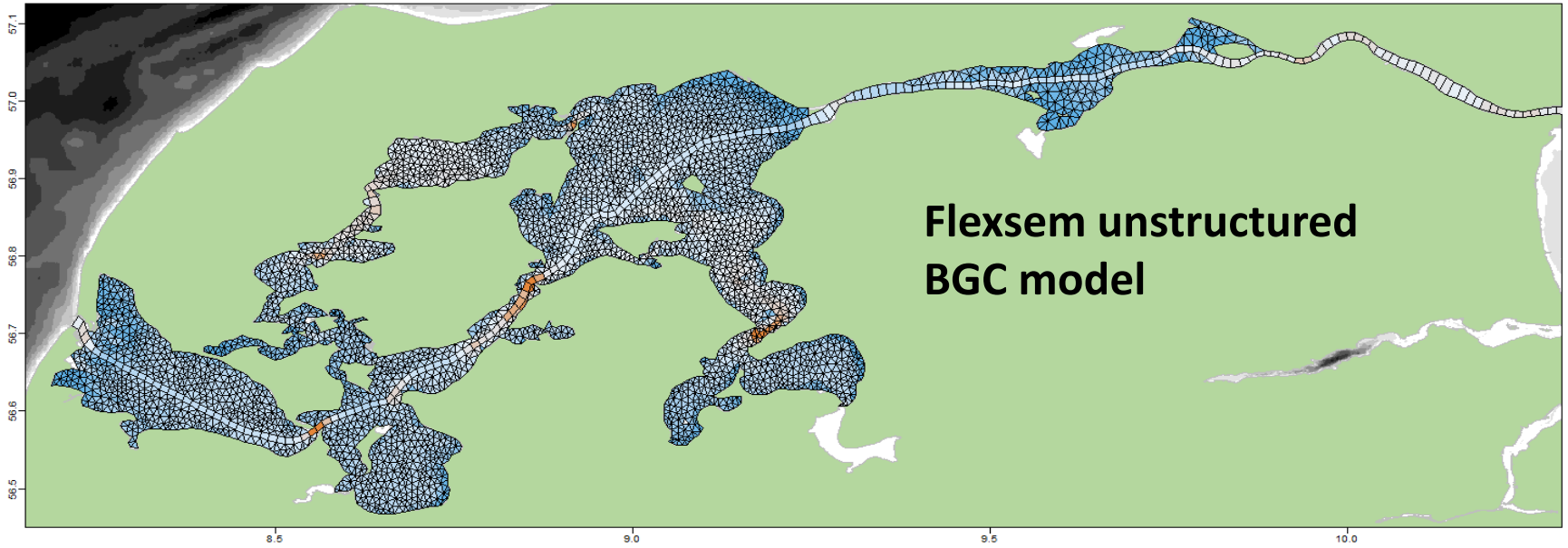

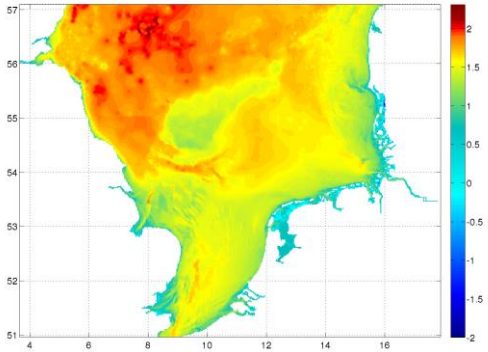

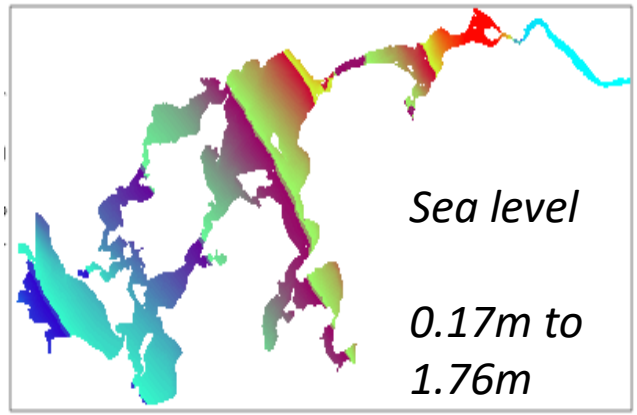

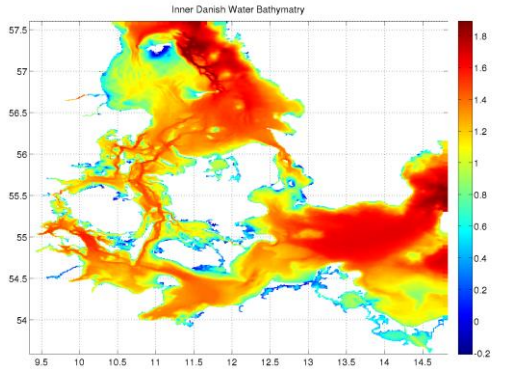

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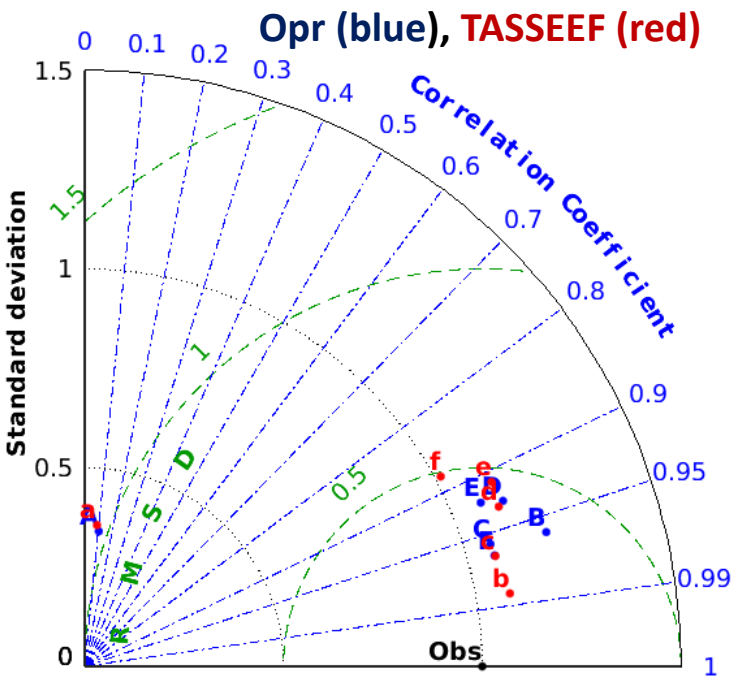
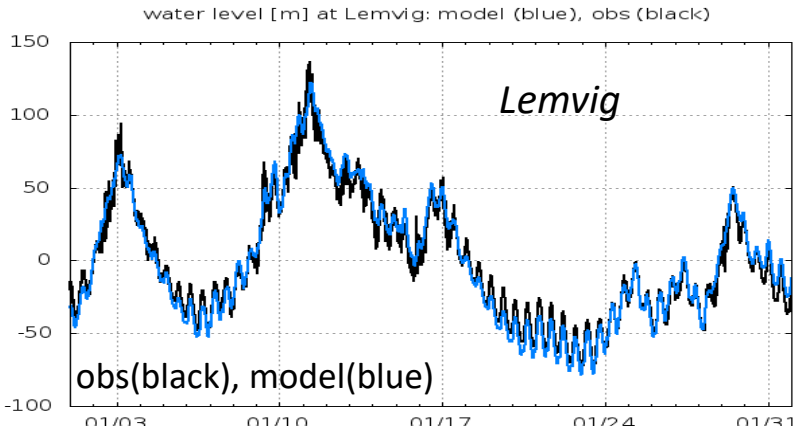
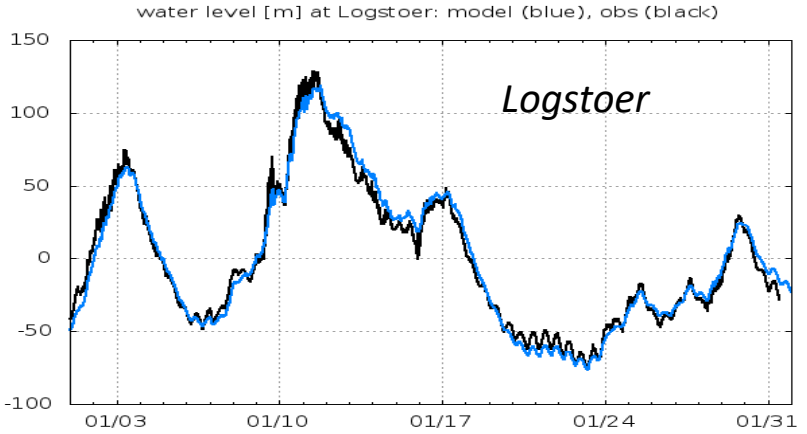
Sea Level validation,

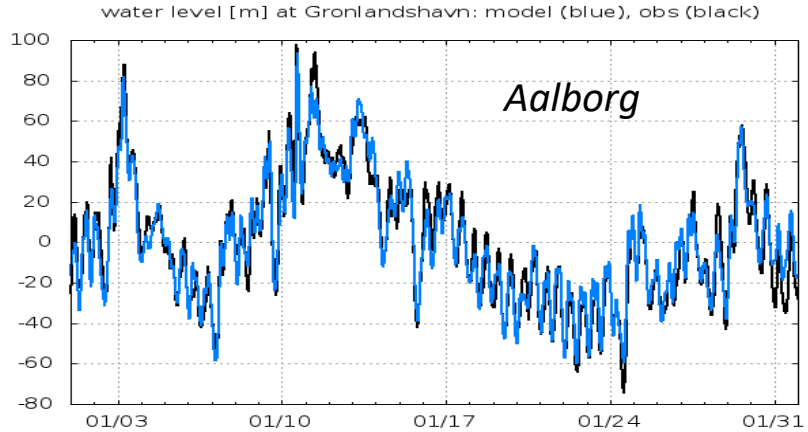
January Storm 2015

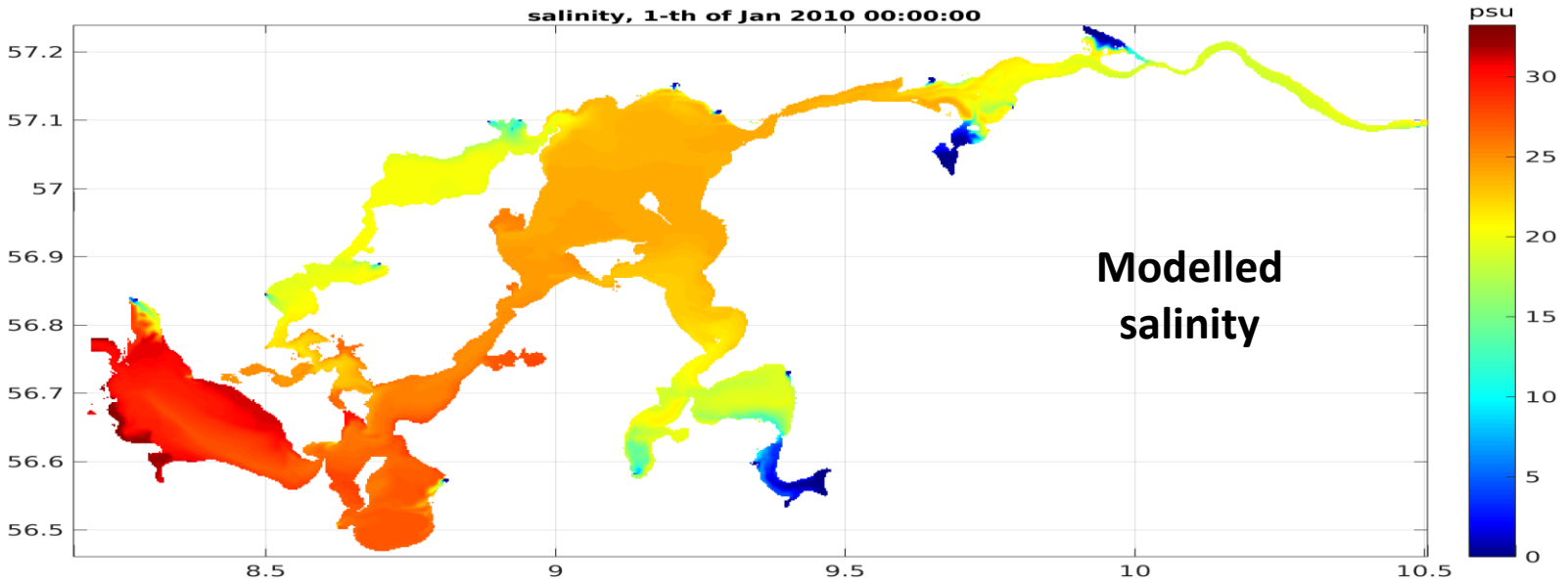


- Western Limfjord: Lemvig (B), much improved
- Central Limfjord: Ny.Mors (C), Thisted (D) improved, but rather comparable
- Central, Eastern Limfjord: slight decrease in performance at Logstoer (E) and Gronlandshavn–Aalborg (F)








salinity, 1-th of Jan 2010 00:00:00
psu
Modelled salinity
57.2
57.1
57
56.9
56.8
56.7
56.6
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25
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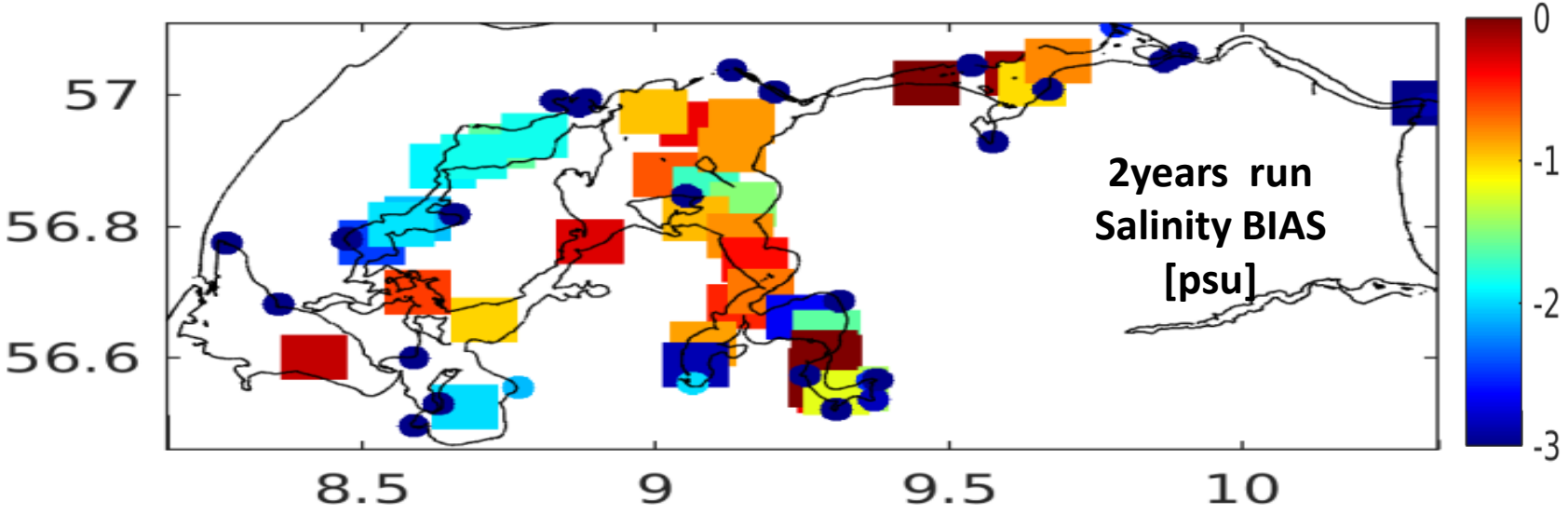
2years run Salinity BIAS [psu]
57
56.8
56.6
8.5
9
9.5
10
0
-1
-2
-3

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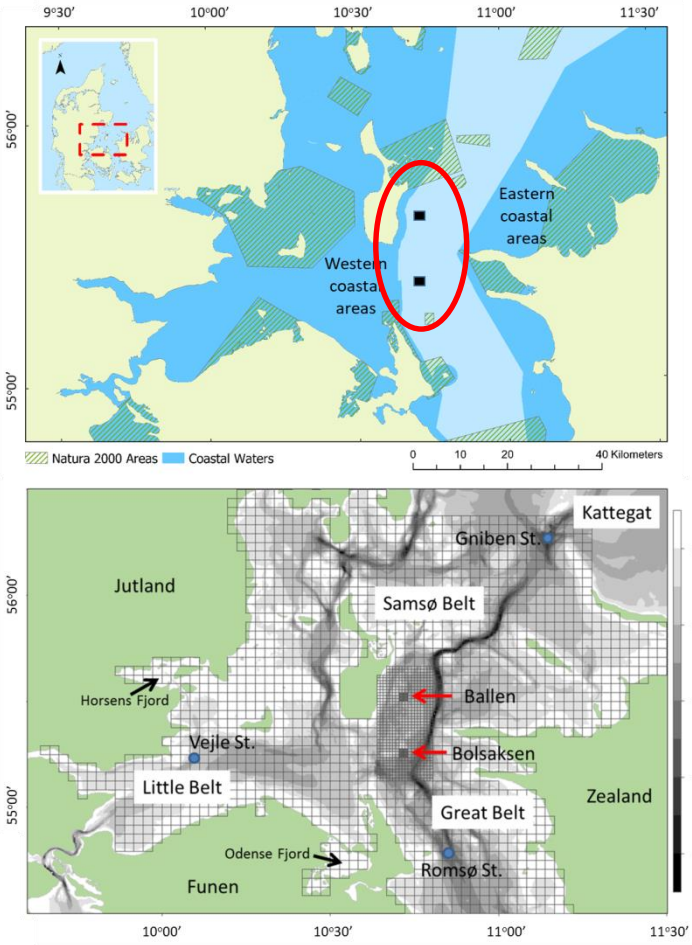
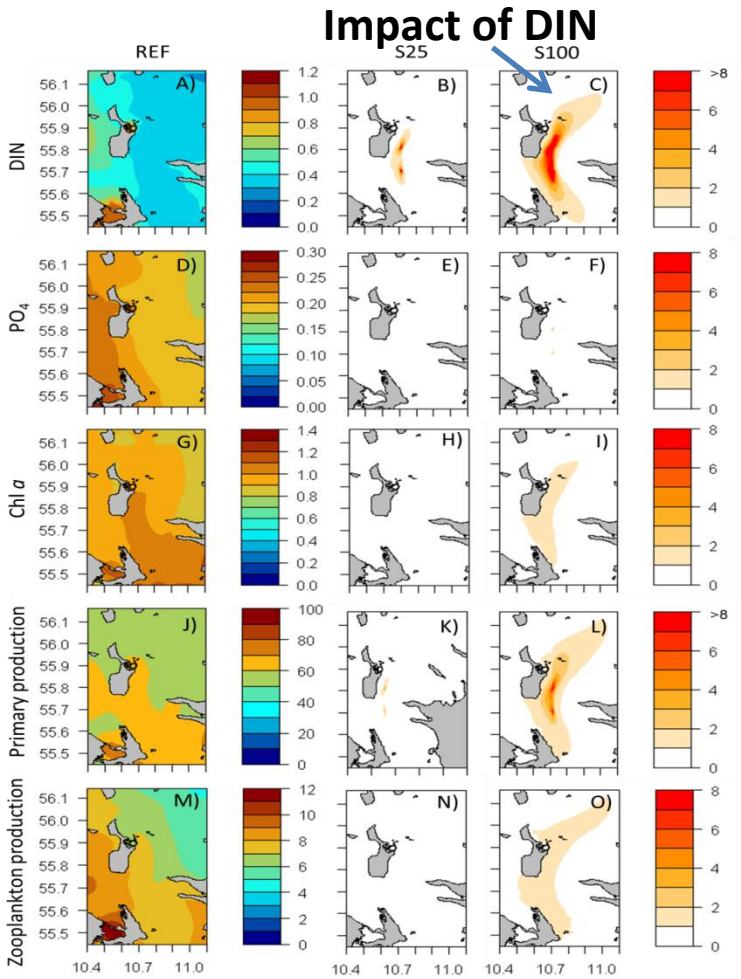
Using HBM-Flexsem to assess the environmental impacts of future offshore fish farms in the inner Danish waters (Maar et al. 2018, AU)



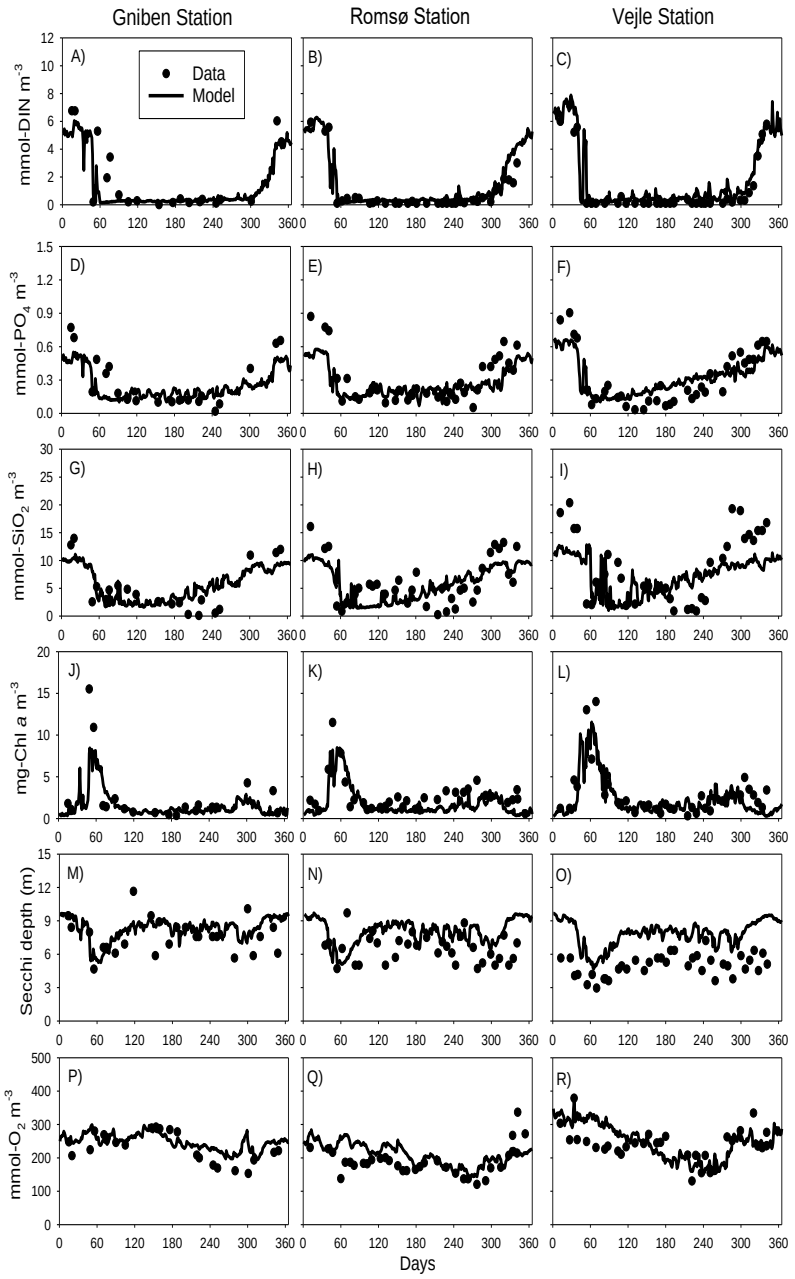


Natura 2000 areas impacted but minor change in coastal waters

Validation of HBM-Flexsem model

	R^2			PMB (%)		
	Gniben	Romsø	Vejle	Gniben	Romsø	Vejle
Surface						
Temperature	0.99	0.99	0.96	8	9	6
Salinity	0.80	0.90	0.77	-18	-13	-15
DIN	0.81	0.96	0.92	-23	-20	-15
PO_4	0.80	0.87	0.90	-14	12	1
SiO_2	0.71	0.69	0.55	3	-5	-18
Chl a	0.66	0.82	0.83	-35	-28	-19
Primary production	-	0.85	0.88	-	25	26
Secchi depth	0.49	Ns	0.81	10	20	38
Bottom						
Temperature	0.86	0.88	0.91	28	23	16
Salinity	0.78	0.62	0.65	-10	-16	-25
DIN	Ns	Ns	Ns	-1	-3	32
PO_4	Ns	Ns	Ns	-25	-8	-10
SiO_2	Ns	Ns	Ns	-31	-16	-1
O_2	0.73	0.33	0.61	8	11	5

R^2 and percentage model bias



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Summary

- For MSFD, an **integrated approach** is needed by breaking existing institutional, sectorial and technical barriers, to generate added value by using all available data & toosls
- Current Copernicus services deliver an intermediate rather than an **end2end** service for MSFD in coastal waters with coarse resolution
- Tailored products from current Copernicus services are useful for MSFD implementation, should be further developed by working together with users
- In-situ provides high resolution coastal data but not fully collected & disseminated, and rarely been used in MSFD assessment
- Sentinels provide chl-a and ocean optics data with good resolution for coastal waters; new satellites SWOT and CFOSAT will also enhance coastal water monitoring in sea level, waves & winds
- At national level, strong modelling capabilities have been developed in ~100m reso. to resolve physical-BGC variables in coastal-estuary continuum
- Emerging modelling capabilities are under development for SPM, plastic litter and underwater noise.

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Recommendations

Emerging Operational modelling capacities should be developed for

- SPM transport
- Plastic litter drifting
- Underwater noise propogation
- Algae bloom
- Oxygen depletion
- Low & High trophic levels

in Basin scale and

- Physical-BGC-Wave-SPM-Pollutant

in catchment-estuary-coastal continuum, by

- Carrying out corresponding research & coastal observing experiments

Bridging Copernicus (incl. downstream) services by

- Developing tailored products at both Copernicus and national level for MSFD/WFD
- More data collection and dissemi., especially for river, SPM, marine litter and underwaternoise data
- **Integrated use of in-situ, remote sensing and modelling for coastal water management (incl. assimilation)**
- Seamless modelling to resolve coastal-estuary-catchment continuum
- Enhanced resolution in Copernicus services to sub-kilometric scale

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Thank you for your attention