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Future forecasting service and related challenges on modelling, observing and their integration

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Introduction to the survey

- **Rational:** forecasting capacity is at the centre of operational service
  - **Identify forecast challenges**: for future seamless forecasting, 38 physical-BGC forecasting challenges (mainly for the coastal-shelf seas) have been identified.
  - **The objective of the survey:**
    - Understand current status of forecasting capacities: advancement level, commonality and variability
    - Near future planning on improving forecast capacities
    - Ecpectations in 5 year time
    - R&D activities needed
    - Observation and monitoring needed
  - **Attendees:** research managers and contact points of all EuroGOOS partners
- **Outcome**:
  - 17 institutes replied, representing Arctic, Baltic Sea, North Sea, IBI, NE Atlantic and Med. Sea
  - Due to limited time, results from MDK has not been included in this presentation

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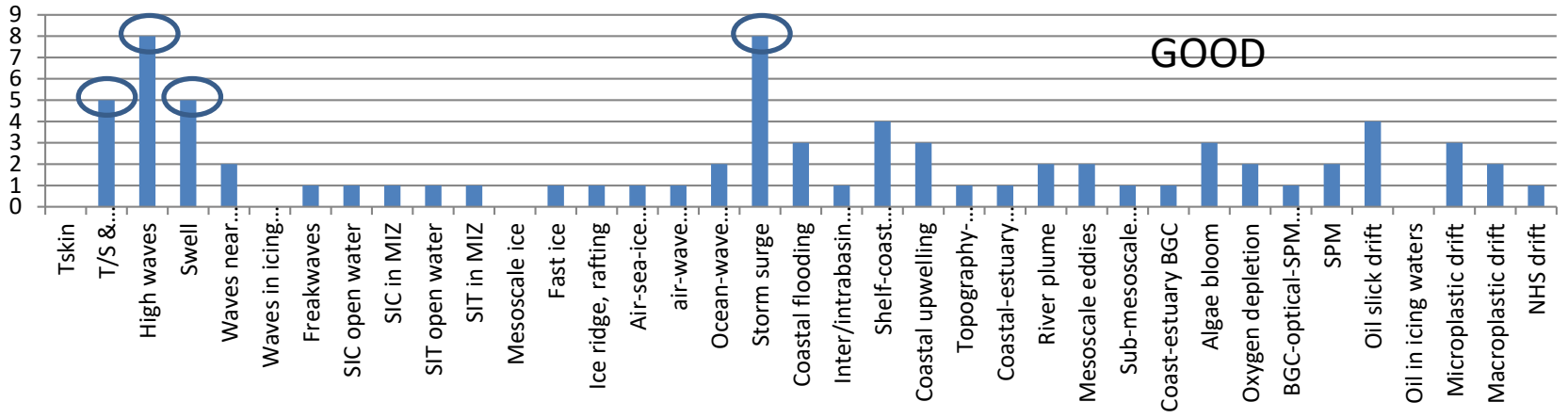
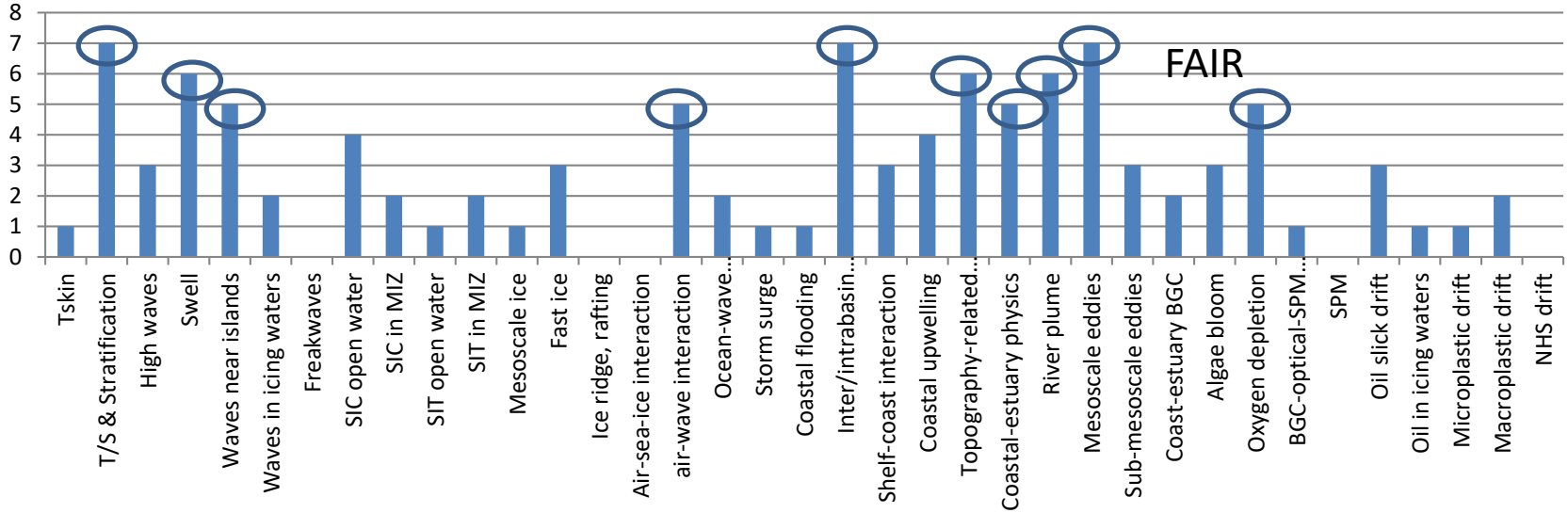
Good and fair forecast capacities: current and in 5 years





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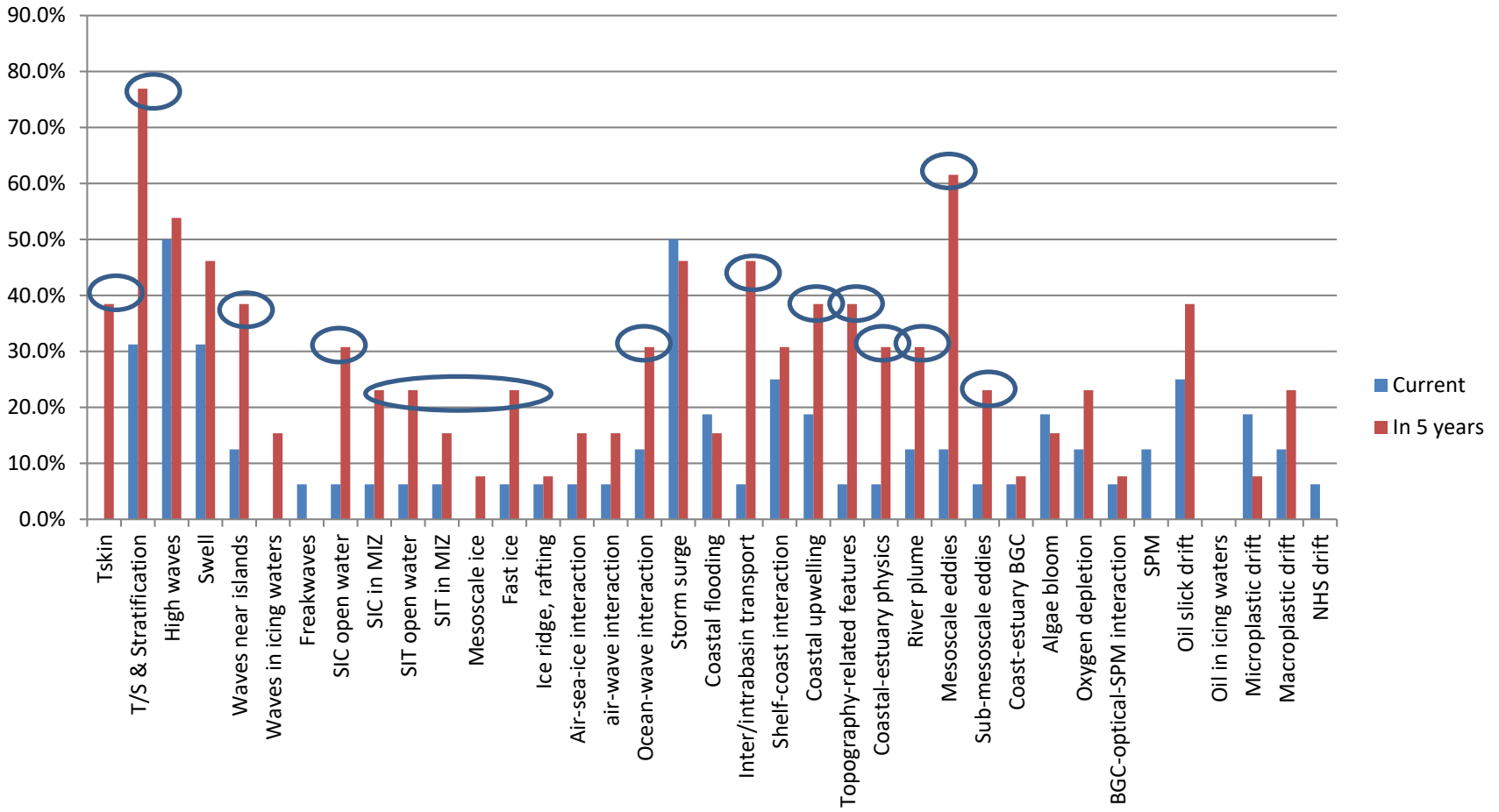
Good forecast capacities: current and in 5 years



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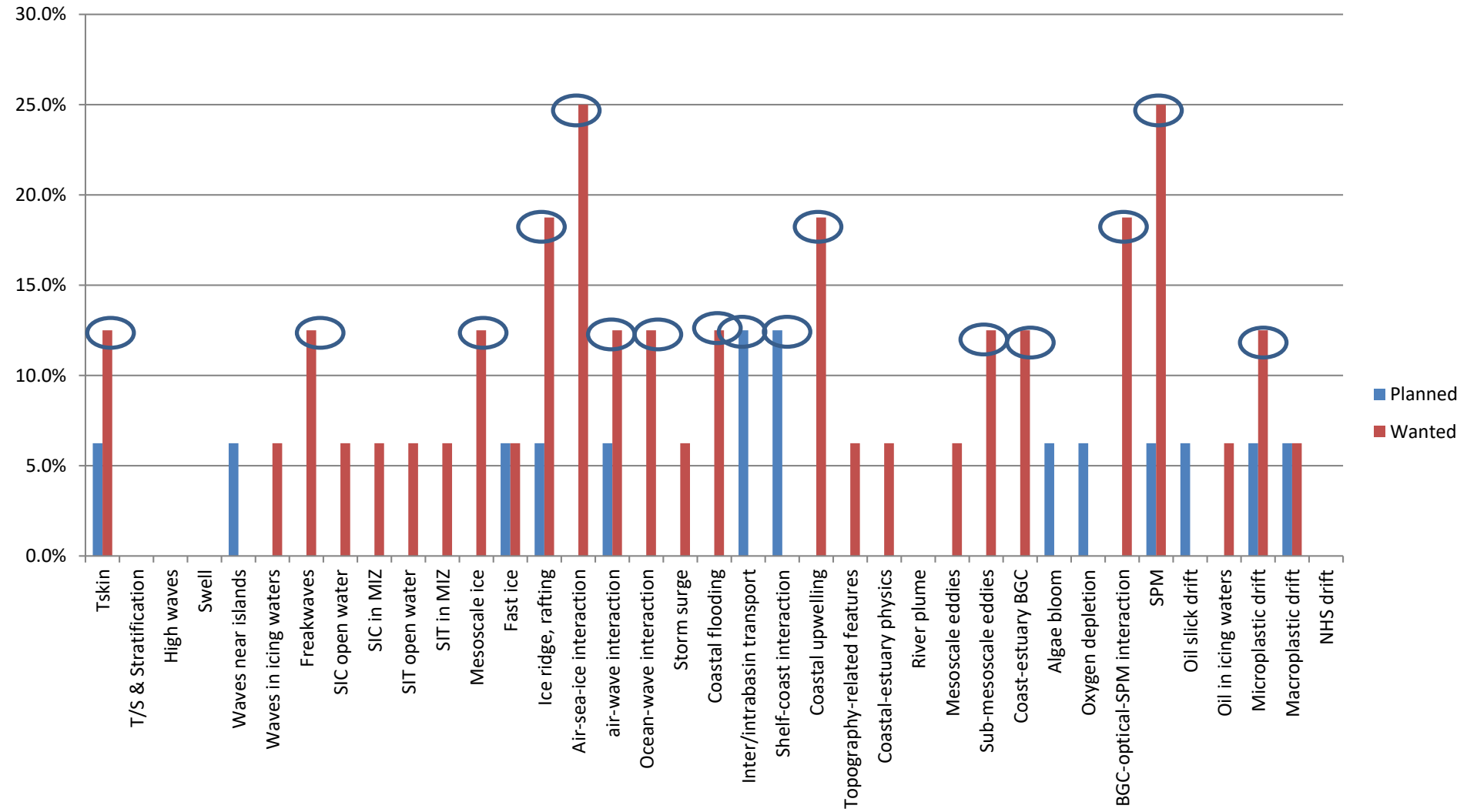
Planned and wanted capacities



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Mid-term (5year) capacity development

	Area	Arctic	Baltic	Baltic-North Sea		North Sea	NW Shelf	NW Shelf,	Atlantic	IBI	Med. Sea	Med Sea	Med. Sea	Med. Sea
3		NERSC	FMI	DMI	BSH	HZG	RBINS	MetO	PLOcean	MI	INOGS	DUTH	IZOR	LEM
4	Tskin	NA	NA	tested	Good	N/A	NA	TBI	Good	Good	N/A	Good	Fair	Good
5	T/S & Stratification	Good	Good	Good	Good	N/A	Good	Good	Good	Good	N/A	Good	Fair	Good
6	High waves	Fair+	Good	Good	N/A	N/A	Fair	Good	Good	Good	N/A	Good	Fair	Good
7	Swell	Fair	Fair	Fair	N/A	N/A	Good	Good	Good	Good	N/A	Good	Fair	Good
8	Waves near islands	TBI	Good	Good	N/A	N/A	Good	Good	TBI	Good	N/A	Planned	Fair	Fair
9	Waves in icing waters	Fair	Good	Good	N/A	N/A	N/A	Fair	TBI	N/A	N/A	N/A	N/A	N/A
10	Freakwaves	N/A	N/A	TBI	N/A	N/A	TBI	NA	TBI	N/A	N/A	N/A	N/A	N/A
11	SIC open water	Good	Good+	Good	Good	N/A	N/A	Fair	TBI	N/A	N/A	N/A	N/A	N/A
12	SIC in MIZ	Fair	Good+	Good	Good	N/A	N/A	Fair	TBI	N/A	N/A	N/A	N/A	N/A
13	SIT open water	TBI	Good	Fair	Good	N/A	N/A	Fair	Good	N/A	N/A	N/A	N/A	N/A
14	SIT in MIZ	TBI	Good	Fair	Good	N/A	N/A	Fair	TBI	N/A	N/A	N/A	N/A	N/A
15	Mesoscale ice	Fair	Fair+	tested	Fair	N/A	N/A	Wanted	Good	N/A	N/A	N/A	N/A	N/A
16	Fast ice	Good	Good+	Fair	Good	N/A	N/A	Fair	TBI	N/A	N/A	N/A	N/A	N/A
17	Ice ridge, rafting	Fair	Good	Fair	Fair	N/A	N/A	TBI	TBI	N/A	N/A	N/A	N/A	N/A
18	Air-sea-ice interaction	tested	Fair	Fair	Fair	N/A	Wanted	Good	Good	N/A	N/A	N/A	N/A	N/A
19	air-wave interaction	tested	Fair	Fair	N/A	N/A	Planned	Good	Good	Tested	N/A	Wanted	Fair	Fair
20	Ocean-wave interaction	tested	Good	Good	N/A	N/A	Fair	Good	Good	Fair	N/A	Wanted	Fair	Fair
21	Storm surge	Fair	Good+	Good	Good	N/A	Good	Good	TBI	Good	N/A	Wanted	Fair	Fair
22	Coastal flooding	N/A	NA	Good	N/A	N/A	Wanted	Good	TBI	Fair	N/A	Tested	Fair	Fair

Red: means capacities expected to be improved

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Mid-term (5year) capacity development

23	Area	Arctic	Baltic	Baltic-North Sea		North Sea	NW Shelf	NW Shelf,	Atlantic	IBI	Med. Sea	Med Sea	Med. Sea	Med. Sea
24		NERSC	FMI	DMI	BSH	HZG	RBINS	MetO	PLOcean	MI	INOGS	DUTH	IZOR	LEM
25	Inter/intrabasin transpo	Good	Good	Good	Good	N/A	N/A	Good	TBI	Good	N/A	Tested	Fair	N/A
26	Shelf-coast interaction	Good	N/A	N/A	Good	Tested	Fair	Good	TBI	Good	N/A	Planned	Fair	Fair
27	Coastal upwelling	Good	Fair+	Good	Good	N/A	N/A	Fair	Good	Good	N/A	Planned	Fair	Fair
28	Topography-related fea	Good	N/A	Good	Good	N/A	Good	Fair	TBI	Fair	N/A	Wanted	Fair	Good
29	Coastal-estuary physics	NA	Fair	Good	Good	Tested	Good	TBI	TBI	Fair	N/A	Fair	N/A	Good
30	River plume	N/A	N/A	Good	Good	Tested	Good	Fair	TBI	Fair	N/A	Fair	N/A	Good
31	Mesoscale eddies	Good	Fair	Good	Good	N/A	Good	Good	Good	Good	Fair	Planned	Fair	Good
32	Sub-mesoscale eddies	tested	Fair	Fair	Fair	N/A	Good	Fair	TBI	Good	Fair	Planned	Fair	Good
33	Coast-estuary BGC	N/A	NA	Fair	Fair	N/A	tested	TBI	TBI	N/A	N/A	Wanted	N/A	Good
34	Algae bloom	Fair	NA	Good	Fair	Tested	tested	Good	TBI	TBI	Fair	Fair	N/A	N/A
35	Oxygen depletion	TBI	NA	Good	Good	Tested	tested	Good	TBI	TBI	Fair	Fair	N/A	N/A
36	BGC-optical-SPM interaction	TBI	NA	tested	Planned	N/A	tested	Good	TBI	N/A	Fair	Tested	N/A	N/A
37	SPM	N/A	Fair	Fair	Planned	N/A	TBI	NA	TBI	N/A	N/A	Fair	N/A	Fair
38	Oil slick drift	TBI	Good	Good	Good	N/A	Good	NA	TBI	N/A	N/A	TBI	N/A	Good
39	Oil in icing waters	Tested	TBI	Tested	Fair	N/A	Wanted	NA	TBI	N/A	N/A	TBI	N/A	N/A
40	Microplastic drift	Tested	NA	Fair	Tested	Planned	Wanted	NA	TBI	Good	N/A	TBI	N/A	Good
41	Macroplastic drift	Tested	NA	Fair	Planned	N/A	Wanted	NA	Good	Good	Tested	TBI	N/A	Good
42	NHS drift	N/A	NA	NA	N/A	N/A	Fair	NA	TBI	N/A	N/A	TBI	N/A	N/A

Red: means capacities expected to be improved

Summary on current and future forecast capacities

- Advancement level:
  - Good forecast: high waves and storm surge (50%); T/S, stratification and swell (31%)
  - Fair forecast: T/S, stratification, swell, waves near islands, air-wave coupling, inter-basin transport, coastal-estruary, river plume, mesoscale, topo, oxygen depletion
  - Less advanced area: skin temperature, freak waves, SIT, ice ridge/rafting, atmosphere-ocean coupling, BGC-optics-SPM coupling, SPM, oil drift in icing waters. Coastal flooding and plastics modelling are also under-developed areas.
- Future capacity in 5 years
  - Atmosphere-ocean-ice coupling, SPM, BGC-optics-SPM coupling, coastal upwelling and ice ridge/rafting are the most wanted features
  - Planned activities are much less than ”wanted” ones. Inter-/intra-basin transport, and coastal-shelf interaction are the top two planned activities, others include palstic modelling, SPM, algae bloom, skin temperature, oil drift etc.
- Limitations:
  - The results may be biased due to following reasons:
    - Only 17 out of 44 EuroGOOS partners participated the survey
    - The person who answered the survey may not be the one who is in charge of forecast development
    - Some participants are non-operational institutes

Area	Arctic	Baltic	NW Shelf, Global	Atlantic/IBI	Med. Sea
Waves (high & freak, swell, etc.)	coupling weather forecasting, HR modeling, Breaking of ice, nonlinear wave modeling	3D ocean-atmosphere, wave-ice coupling, improved subgridscale modelling, unresolved islands, bathymetry, refraction, reflection, EPS	EPS,DA, HR / grids, better use of computational resource (domain decomposition)	Sustainable platform/ sensing for continuous monitoring + DA tools and protocols + best practices, HR near coasts	DA, HR, EPS, Improved grids, flooding capacity
Ice (concentration, thickness, dynamics, etc.)	Sea ice rheology, melt ponds, Ocean currents, weather-snow-ice interface, Ice DA, upper layer mixing, better use satellite data	increased resolution, coupled models, new rheologies, prognostic parameterisation of fast ice, ice DA, upper layer mixing			
T/S (skin temperature, stratification, etc.)	DA (T/S), Improved turbulence mixing	DA (T/S), improved turbulence mixing, wave-ocean coupling, Tskin prediction model	DA (T/S), Improved turbulence mixing	Sustainable platform/ sensing for continuous monitoring + DA tools and protocols + best practices, Improved atmospheric forcing (HR), HR of models near coasts	
Storm surges	Consistency with 3D ocean, improved resolution, bathymetry, drag	Ensembles, improved resolution, bathymetry, unstructured grids, drag	Sub-surface platforms eg gliders, EPS, DA, HR, improved understanding of tide / surge aliasing, bathymetry, drag		Sensor deployment for model validation and DA, Flooding capability, HR

Area	Arctic	Baltic	NW Shelf, Global	Atlantic/IBI	Med. Sea
Inter-basin transports	Improved ocean model numerics, bathymetry	Improved grids (unstructured), HR, bathymetry	higher resolution and improved bathymetry	Sustainable platform/sensing for continuous monitoring + DA tools and protocols + best practices, validation and mapping, HR coastal models	DA, Improved grids
Coastal Upwelling	better atmos. momentum, coupling, mixing	Ocean-wave(-atmosphere) coupling, increased resolution	better atmos. momentum, coupling, mixing		DA, Improved grids, HR atmospheric forcing
Shelf-cost interaction	Improved ocean model numerics, bathymetry		HR, numerics / vertical grids, sub-mesocale parameterisation, bottom sensors and modelling		DA, HR, land-sea interaction (earth system model)
Mesoscale & sub-mesoscale dynamics	Improved model numerics, higher resolution, DA;	Improved resolution, DA; SAR/ferrybox	Resolution, atmo-wave-ocean coupling, Improved resolution, DA; SAR/ferrybox		DA, EPS, increasing resolution, Turbulence and mixing
River plume		Improved resolution, river temp., DA	Fully land surface /atm / ocean coupling, HR, river temp., DA, extremes, EPS	need realistic river runoffs rather than climatologies	EPS, HR, coupling, Better river forcing, Integrated watershed-coastal zone model development

Area	Arctic	Baltic	NW Shelf, Global	Atlantic/IBI	Med. Sea
Algae bloom	Optical properties, mixed layer, BGC modeling	Skin temperature forecast, chl-a DA, BGC modelling, parameterizations, DO reinitialization, coupling of BGC model to SPM dynamics	Improved BGC model & DA (incl multivariate-optical), HR, decoupling with the ocean (i.e DEGRAD), Tskin forecast, parameterizations DO reinitialization, Use of IOP model and DA, BGC-SPM coupling	Sustainable platform and sensing for continuous monitoring + DA tools and protocols + best practices, develop bgc models	improve BGC parameterization, sensor deployment, coupling spectral optical model with BGC model
Oxygen depletion					
BGC-optical-SPM-physical interaction					
Suspended sediment transport	N/R	Further calibration and process study	Further calibration and process study	Sustainable platform and sensing for continuous monitoring + DA tools and protocols + best practices, Parameterize particle tracking models, e.g. include windage effects for macroplastics, release drifters for validation	DA, Improved grids
Pollutant drift (oil slick, micro & macro plastic, NHS, etc.)	Diffusion	Wave-ice-ocean coupling, oil drift in ice, R&D on monitoring and modelling of micro-/macro plastics, resolving wave-induced transport, sedimentation, resuspension and biofouling, code optimization, automatization, better input data, EPS	Microplastics from VOS, code optimization, automatization, better input data, ensemble modelling, DA		Improve hydrodynamic model grid resolution, DA, EPS

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Summary on R&D for forecast challenges

- Different regions give different R&D priorities
- EPS, DA, HR and coupling are common ones
- Improved bathymetry, grid and drag in Baltic-North Sea
- Extensive model validation needed
- Processes: ice rheology, submesoscale eddies etc.
- There are still lack of roadmaps to address the ”emerging” forecasting challenges

Area	Arctic	Baltic	NW Shelf, Global	Atlantic	Med. Sea
Waves (high & freak, swell, etc.)	Wave spectra from satellite once per day, SAR coverage once per day, wave buoys in high Arctic (Svalbard, Greenland, East Siberian Isl., Jan Mayen), Floe size distribution, ice classification, wave buoys (super resistant)	Coastal wave observations, improved nearshore satellite wave data, wave observations from partly ice-covered areas	HF Radar, in situ wave observations	Sustainable platform and sensing for continuous monitoring	HF radar needed, wave buoys, satellites
Ice (concentration, thickness, dynamics, etc.)	Passive Microwave (big antenna) daily, passive Microwave (big antenna), ice drift daily, Snow depth, Ice Mass Balance buoys, EM surveys, Radar altimeters, low-freq. passive microwave (SMOS) +/-10% accuracy, ice drift daily from SAR ice drift daily at 5 km resolution, bathymetry, satellite SAR daily, visible satellite coverage	improved classification of satellite data for assimilation			
T/S (skin temperature, stratification, etc.)	Moorings and satellite winds, waves, surface currents, surface winds and waves at HR from satellites, currents and waves from satellites (SKIM); Argo floats and Ice-Tethered Profilers	Air-sea flux, open sea weather stations, in-situ/satellite wind, waves, currents, T/S and waves; NRT delivery of CTD data, NRT Argo data from all sub-basins, NRT Glider data, CFOSAT data, in situ Tskin & profiles	Flux observations, CFOSAT data, in-situ wind and waves, in situ currents and waves; in situ Tskin &		

Area	Arctic	Baltic	NW Shelf, Global	Atlantic/IBI	Med. Sea
Storm surges	Improved processing of satellite altimeter, tide gauges in High Arctic	Nearshore SLA, more offshore data for validation	HF radar, SWOT, more offshore data	Sustainable platform and sensing for continuous monitoring, satellite geostrophic currents in-situ temperature sensors, satellite SST, satellite sea level	Tide gauges, wave buoys, LIDAR bathymetry/topography, HF radar,
Inter-basin transports	Mooring arrays, regular sections; hydrographic sections	in-situ currents, T/S & nutrients in Danish straits-Arkona, Baltic Proper-Åland Sea – Bothnian Sea, and at the entrance and centre of subbasins	in-situ currents, T/S and nutrients in Danish Straits, and at the entrance and centre of subbasins		CTD and ADCP moorings
Coastal Upwelling	SST and hydrographic sections in upwelling areas	In-situ SST, T/S profiles and currents in upwelling areas	In-situ SST and currents in upwelling areas		BGC-glider and fixed buoys with BGC-sensors, HF radar
Shelf-coast	Moorings		Improved sharing of coastal data, offshore measurements		BGC-glider, BGC-buoys, gliders, ADCP moorings
Meso/sub mesoscale	SAR, SST, SWOT, SKIM, drifters	SAR, SST, ferrybox, glider	SWOT, SAR, SST, FB, glider, HF radar		HF radar measurements
River plume	SAR, floats, moorings; River inputs from hydrological models	In situ currents, T/S in areas with complex topography; Near-shore satellite data, in-situ T/S, waves, currents, chl-a, nutrients, FB, SAR, Sentinel chl-a, river loads	SAR, in-situ T/S, currents; Sentinel chl-a, river loads, in-situ chl-a, nutrients, ferrybox, nutrient and CDOM sensors		Flow measurements, HF radar, satellites

Area	Arctic	Baltic	NW Shelf, Global	Atlantic/IBI	Med. Sea
Algae bloom	Ocean colour daily, bio-Argo; satellite chl-a, river loads, in-situ chl-a, nutrients, ferrybox; Nutrient fluxes from hydrological models	Dedicated field experiments for algae bloom process study; SAR, Sentinel chl-a, river loads, in-situ chl-a, nutrients, ferrybox, DO, pCO2, pH, Chl sensors	Bio Argo, DO, pCO2, pH, Chl sensors, SAR, Sentinel chl-a, river loads, in-situ chl-a, nutrients, ferrybox	Sustainable platform and sensing for continuous monitoring, more in-situ data for validation, clear guidance on which satellite product(s) is best for a given area, more in-situ platforms (fixed, Argo, gliders)	BGC-Argo and BGC-glider, on-line sensor
Oxygen depletion	O2 measurments, Bio-ITPs	Increased moorings with bottom DO measurements, more sub-surface measurements	Bio Argo, more sub-surface measurements, Bottom water DO sensors		BGC-Argo float (Delayed mode PQ for oxygen), on-line sensor
BGC-optical-SPM	Ocean colour daily, bio-Argo	dedicated field experiments needed	dedicated field experiments needed		
Suspended sediment transport	SPM from Arctic rivers	In -situ and satellite SPM observation, near-bottom currents	In -situ and satellite SPM Observation needed, Turbidity sensors	Sustainable platform and sensing for continuous monitoring	Measurements needed
Pollutant drift (oil slick, micro & macro plastic, NHS, etc.)	Surface currents from space (SKIM), Oil slicks in sea ice and below sea ice, ice drift; sources of microplastics & macroplastics	drift/mixing measurements, new monitoring data of micro- and macroplastics, and source mapping,	data of drift experiments, new monitoring data of micro-macro plastics, and source mapping		Satellite

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Summary on ocean observing needs for forecast challenges

- Use of new satellite observations: SAR, SWOT, SKIM, CFOSAT, Sentinels etc.
  - Data assimilation
  - Observation analysis.
- Use of high resolution coastal data to address emerging areas in coastal-estuary continuum, small scale phenomenon.
- NRT delivery of CTD and nutrient data
- New observations for emerging challenges
- Establish useful databases
- Dedicated field experiments and integrated modelling-observation analysis to address ”emerging” forecasting challenges

Final remarks

- The survey should be further improved with inputs from more partners and corrected inputs from the right persons
- Existing outcomes are already inspring.
- The outcomes should be disseminated to ROOSs for further exploitation
- ROOSs should enrich the existing outcomes for developing a strategy on developing future regional seamless forecast capacity

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Thank you for your attention