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Implementation of EuroGOOS scientific strategy by developing forecasting capacities

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EuroGOOS scientific strategy in next 5-10years

- Four priority areas
  - **European ocean observations**: EOOS, integration of opr.-non-opr. monitoring
  - **Modelling and Forecasting technology**: unified ocean models, seamless modelling
  - **Coastal Operational Oceanography**: estuary-coastal-sea continuum; sediment/pollutant drift forecast, disaster prevention, sectorial operational/senario services etc
  - **Operational Ecology**: scientific basis for OE, integrated monitoring-modeling-forecasting-projection, indicator products, services

She, J., Allen, I., Buch, E., Crise, A., Johannessen, J. A., Le Traon, P. Y., Lips, U., Nolan, G., Pinardi, N., Reißmann, J. H., Siddorn, J., Stanev, E., and Wehde, H., 2017: Developing European operational oceanography for Blue Growth, climate change adaptation and mitigation and ecosystem-based management, *Ocean Science.*

How to implement EuroGOOS scientific strategy in a volunteered organization?

From the Earth System Science for Global Sustainability: The Grand Challenges, ICSU, 2010

- Service needs at national level
- Forecasting bridges R&D, observing and service.
- A survey on forecasting capacity and challenges was designed and carried out by the SAWG

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Introduction to the survey

- **Survey design**
  - **Identify forecast challenges**: 38 physical and biogeochemical forecasting challenges (mainly for the coastal-shelf seas) have been identified.
  - **The objective of the survey:**
    - **Current status of capacities** on the forecasting challenges
    - **Expected capacities** in 3-5 year time
    - **R&D activities needed**
    - **Observation and monitoring needed**
  - **Attendees:** research managers of all EuroGOOS partners
- **Outcome**:
  - 6 institutes replied, ie, DMI, BSH, FMI, MI, Met.O and NERSC, representing Baltic Sea, North Sea, NE Atlantic and Arctic Ocean.

- We can predict high waves, swell and storm surge in open coast in **good quality**
- Waves near complex topography, open water ice concentration, stratification, coastal-shelf interaction, upwelling and topography-related features can be predicted with **fair quality**

Survey on forecasting capacity – EuroGOOS WG (Good, Fair, TBI, Tested, N/A)												
	Current capacity						Capacity in 3 years					
Physical forecasting	DMI/ BAL MFC	BSH	FMI	MI	METO	NERSC	DMI	BSH	FMI	MI	METO	NERSC
High waves	Good	Good (DWD)	Good	Good	Good	Fair+	Good+	(DWD)	Good+	Good+	Good+	Fair+
Swell	Fair	Good (DWD)	Fair	Good	Good	Fair	No plan	(DWD)	No plan	Good+	Good+	No plan
Storm surge in open coasts	Good	Good	Good	Good	Good	N/A	Good+	Good+	Good+	Good+	Good+	Tested
Waves near islands, complex topography	TBI		Fair+	Fair	Fair	TBI	Good	(DWD)	Good	Fair+	Good	Fair+
Ice concentration in open waters	Fair	TBI	Good	N/R	Fair	Fair	Fair+	Fair	Good		Fair	Fair+
Inter-basin transport	Fair	Good	Fair	Fair		Fair	Good	Good	Good	Fair+		No plan
Inter-sub-basin transport	TBI	TBI	Fair	Fair	None	Fair	Fair	Fair	Good	Fair+		No plan
T/S & Stratification	Fair	TBI	Fair	Fair+	Fair	Fair	Good	Fair	Good	Good	Good	Good
Shelf-coastal interaction	N/R	TBI	N/R	Fair	Fair	Fair				Fair+	Fair	No Plan
Coastal upwelling	TBI	Fair	Fair	Fair	Fair	Fair	No plan but wanted	Good	Fair+	Fair+	Fair	No Plan
Topography related ocean features	Fair	Fair	Fair	Fair	Fair	Fair	Good	No plan	Fair+	Fair+	Good	No Plan

- Waves in icing waters, SIC in marginal waters and SIT, mesoscale ice, fast ice, river plumes and coastal-estuary-continuum still **needs improvements**
- Ice ridging, rafting, atmosphere-ocean-ice-wave coupling and mesoscale eddies are in R&D **testing phase**

Survey on forecasting capacity – EuroGOOS WG (Good, Fair, TBI, Tested, N/A)												
	Current capacity						Capacity in 3 years					
Physical forecasting	DMI/ BAL MFC	BSH	FMI	MI	METO	NERSC	DMI	BSH	FMI	MI	METO	NERSC
Waves in icing waters	TBI	N/A	Fair	N/R	TBI	Tested	Fair		Fair+			TBI
Ice concentration in marginal waters	TBI	TBI	Good	N/R	None	TBI	Fair	Fair	Good			Fair
Ice thickness in open waters	TBI	TBI	Good	N/R	TBI	TBI	Fair	Fair	Good		Fair	TBI
Ice thickness in marginal waters	TBI	TBI	Good	N/R	None	TBI	Fair	Fair	Good			TBI
Mesoscale ice dynamics	N/A	Tested	Fair	N/R	None	Tested	No plan	Fair	Fair			TBI
Fast ice	TBI	Tested	Good	N/R	TBI	TBI	No plan	No plan	Good		Fair	Good
Coastal-estuary continuum (physics)	River as point source	Fair	Fair	Fair	Wanted	N/A	Fair	Fair	Fair	Fair+	TBI	No Plan
River plume	N/A	Good	N/A	Fair	TBI	N/R	Tested	Good		Fair+	TBI	N/R
Ice ridging, rafting	Tested	Tested	Good	N/R	TBI	Tested	Fair	No plan	Good			TBI
Atmosphere-ocean-ice interaction	ocean-ice	Tested	Wanted	N/R	Good	TBI	Offline coupling		Offline coupling			Ice-waves TBI
Ocean-wave interaction	Tested	Fair+ (one way)	N/A	N/A	Fair	Tested	Online coupling	No plan	Offline coupling	tested	Good	One-way coupling
Mesoscale eddies	N/A	Fair	N/A	Fair	Tested	Fair	Tested	No plan	Tested	Fair+	Fair	Fair

- Prediction of skin-temperature, freak waves, storm surge in fjørds and submesoscale eddies is **yet to be developed**
- Oil slick drift prediction: **good quality;** Oxygen depletion prediction: **fair, tested, TBI or N/A**
- BGC-Optics-SPM-Physics interaction and oil slick drift in icing waters: **tested or initiated**
- Coastal-estuary continuum (BGC), algae bloom, SPM, plastics &HNS are **yet to be developed**

Survey on forecasting capacity – EuroGOOS WG (Good, Fair, TBI, Tested, N/A)												
	Current capacity						Capacity in 3 years					
Physical forecasting	DMI/ BAL MFC	BSH	FMI	MI	METO	NERSC	DMI	BSH	FMI	MI	METO	NERSC
Skin temperature	N/A	N/A	N/A	N/A	Fair	N/A	Fair	No plan	No plan			No plan
Freak waves	TBI	N/A	N/A	N/A	None	N/A	No plan		No plan			No plan
Atmosphere-wave interaction	Tested	N/A	Tested	N/R	Fair	N/A	Offline coupling		Offline coupling		Good	Tested
Storm surge in fjord coasts	Fair	N/A	Good	N/R	None	N/A	Good					No plan
Submesoscale eddies	N/A	N/A	N/A	Fair	Tested	N/A	Tested	No plan	Tested	Fair+	Fair	No Plan
Ecosystem, BGC and pollutant drift forecasting												
Oil slick drift	Good	Good	Fair+	Good	N/A	TBI	Good+	Good+	Good	Good		TBI
Oxygen depletion	Tested	Fair	N/A	N/A	Fair	TBI	Fair	Good	No plan		Fair	No Plan
BGC-optical-SPM-physical interaction	Idea phase	Tested (no SPM)	N/A	N/A	TBI	BGC-Physics	?	No plan	No plan		Fair	No Plan
Oil slick drift in icing waters	Tested	N/A	TBI	N/R	N/A	Tested	?	No plan				TBI
Coastal-estuary continuum (BGC)	River as point source	TBI	River as point source	N/A	Wanted	N/A	No plan but wanted		No plan, wanted		Wanted	No Plan
Algae bloom	N/A	TBI	N/A	N/A	TBI	TBI	Tested		No plan		Fair	TBI
SPM	Tested	N/A	Wanted	N/A	TBD	N/A	No plan wanted	No plan	Wanted/ No plan		Fair	No Plan
Microplastic drift	TBD	N/A	N/A	Wanted	N/A	N/A	Tested		No plan	Wanted		No Plan
Macroplastic drift	TBD	Good	N/A	Wanted	N/A	N/A	Tested		No plan	Tested		No Plan
NHS drift				N/A	N/A							

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	Survey on key R&D priorities for improving forecasting – EuroGOOS SAWG
High waves, swell, wave near islands, complex topography Waves in icing waters	- Ensembles, coupling with atmosphere, 3D ocean - Improved techniques for subgridscale modelling, unresolved islands, unresolved bathymetry, refraction, reflection - High resolution coastal models, high resolution atmospheric forcing - Data assimilation; Resolution and the SMC grid; - Wave/ice interactions and the impact upon global ocean modelling; update wave models to use new ice source terms, breaking of ice
Freak waves	Nonlinear wave modeling
Ice concentration and thickness in open and marginal waters	Ice DA (cryosat), upper layer mixing, new ice dynamics, increased resolution, coupled models Sea ice rheology, melt ponds Ocean currents, weather, snow-ice interface
Mesoscale ice dynamics	new ice rheology
Fast ice	increased resolution, prognostic parameter. of fast ice, DA, Ice cavity modelling, ice rheology
Ice ridging, rafting	BALMFC R&D, transition to LIM, ice rheology
Skin temperature	Tskin prediction model
Atmosphere-ocean-ice-wave interactio	Coupling, improved surface layer models/ parameterisations Regional and global coupled system research, basic research, models set-up

	Survey on key R&D priorities for improving forecasting – EuroGOOS SAWG
Storm surge in open coasts	- Ensembles, forecasts/methods - Improved resolution, bathymetry, drag, slope flow
Storm surge in fjord coasts	- unstructured grids - high resolution atmospheric forcing
Inter-basin transport	- coupled processes, consistency with 3D ocean
Inter-sub-basin transport	- Extensive validation required for proper assessment - Overflows, grid refinement
T/S & Stratification	- Improved ocean model numerics, bathymetry
Shelf-coastal interaction	- DA (T/S), Improved turbulence mixing schemes, wave-ocean coupling - Hi-res subsurface DA, OSMOSIS vertical mixing - better boundary data for North Sea - enrollment of high resolution coastal models to all coasts of Ireland (currently only SW and W) - carbon transport
Coastal upwelling	- better atmos. momentum, SST DA,
Topography related ocean features	- improved resolution, bathymetry, grid, slope flow, unstructured grid, model numerics - Ocean-wave(-atmosphere) coupling, improved mixing - extensive validation required for proper assessment - increase coverage of Irish coasts with high resolution models, replace climatologies with observed/ forecasted discharges
Coastal-estuary continuum (physics)	- Improved resolution, river input method, river temp., DA, bathymetry - land/sea interface through coupled solutions
River plume	
Mesoscale eddies	- DA with SAR/ferrybox, observation analysis
Submesoscale eddies	- extensive validation, DA in hi-res systems of hi-res obs - Improved model numerics

	Survey on key R&D priorities for improving forecasting – EuroGOOS SAWG
Coastal-estuary continuum (BGC)	- Improved resolution, river input method, improved river loads, Nutrient fluxes - land/sea interface through coupled solutions
Algae bloom	- Skin temperature forecast, chl-a and Kd DA, parameterizations - Optical properties, mixed layer
Oxygen depletion	- improved resolution, stratification, profile DA, mixing and BGC modeling
BGC-optical-SPM-physical interaction	- PFT assimilation, upgraded sediment model in ERSEM, bio-physical feedbacks
Suspended sediment transport	- Further calibration and process study - SPM model development, sinking velocity
Oil slick drift	- Ensemble prediction
Oil slick drift in icing waters	- Wave-ice-ocean coupling, oil drift in ice - Submesoscale currents, diffusion
Microplastic drift	- CLIAM R&D on source mapping, biofouling-sinking velocity, resuspension - Adapt existing particle tracking capacity for microplastics - CLAIM R&D on IBM modelling,beaching processes, wind forcing parameterization - Interreg Atlantic Area project, building capacity in 3 years
Macroplastic drift	
HNS drift	Good oil spill model exists and a general particle tracking software.

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Summary on R&D for forecast challenges

- Ensemble forecast
- Assimilation
- Coupling atmosphere-ocean-wave-ice and BGC-optics-SPM-physics
- Higher resolution, improved bathymetry, grid and drag
- Extensive model validation needed
- Processes: ice rheology, submesoscale eddies etc.
- Emerging forecast capcities: skin temperature, SPM, plastic litter, algae bloom, storm surge in fjørds etc.
  There are still lack of roadmaps to address the ”emerging” forecasting challenges

N. European Seas	Survey on observation and monitoring needs and requirements – EuroGOOS SAWG survey
High waves	- Satellite based sig wave height at accuracy better than wave model errors
Swell	- Wave spectra from satellite once per day - Satellite SAR coverage once per day
Waves near islands, complex topography	- Coastal wave buoys, - improved nearshore satellite wave data - Wave buoys in high Arctic (Svalbard, Greenland, East Siberian Isl., Jan Mayen)
Waves in icing waters	- Wave observations from partly ice-covered areas - Detailed observations of sea-ice extent and concentration - Floe size distribution, ice classification
Freak waves	- Retrieval of maximum individual wave and crest heights and wave period from buoys and satellite - Wave buoys (super resistant)
Ice concentration, thickness in open and marginal waters	- satellite and in situ data, OSI SAF ice products, Cryosat data - High-resolution products and error estimates - Passive Microwave (big antenna), ice drift daily - synoptic scale ice thickness measurements - Snow depth, Ice Mass Balance buoys, EM surveys, Radar altimeters - Low-freq. passive microwave (SMOS) +/-10% accuracy, ice drift daily from SAR
Mesoscale ice dynamics	- ice drift daily at 5 km resolution
Fast ice	- In situ ice observations, bathymetry, SAR daily
Ice ridging, rafting	- Visible satellite coverage
Skin temperature	- In situ Tskin & profile observations
Atmosphere-ocean-ice interaction	- Air-sea flux measurements, open sea weather stations - Moorings and satellite winds, waves, surface currents
Atmosphere-wave interaction	- CFOSAT data, co-located in-situ and satellite wind and waves
Ocean-wave interaction	- co-located in situ and satellite atmospheric, flux and subsurface ocean obs of T, moisture/salinity and wind/currents - Surface winds and waves at HR from satellites - In situ currents, T/S and waves - Currents and waves from satellites (SKIM)

N. European Seas	Survey on observation and monitoring needs and requirements – EuroGOOS SAWG survey
Storm surge in open coasts	- Nearshore SLA - good network of tide gauges with high frequency (min. 10 minutes) records in real time - HF radar; more still water level and current observations retrieved from offshore platforms - Improved processing of satellite altimeter, tide gauges in High Arctic
Storm surge in fjord coasts	Existing
Inter-basin transport	- in-situ currents, T/S and nutrients in Kategatt-Danish Straits-Arkona, Baltic Proper-Åland Sea – Bothnian Sea, entrance and centre of subbasins
Inter-sub-basin transport	- in-situ currents, underway currents, drifters trajectories, satellite SSH - moored arrays e.g. TAO, RAMA and T/S and turbulence in deep water formation areas - Mooring arrays, regular sections - in-situ currents, underway currents, drifters trajectories, satellite SSH
T/S & Stratification	- NRT delivery of CTD data, Argo data from all sub-basins, Glider data - Mammal borne sensors, gliders - Argo floats and Ice-Tethered Profilers
Shelf-coastal interaction	T/S profile data, CTD casts, currents, Gliders, high resolution satellites, moorings
Coastal upwelling	- In-situ SST, winds, currents, T/S profiles (sections) and currents in upwelling areas - Upwelling indices (e.g. nutrients)
Topography related ocean features	- In situ currents, T/S in areas with complex topography - SAR, drifters, floats, moorings
Coastal-estuary continuum (physics)	- SAR, Near-shore satellite data, in-situ T/S, waves, currents - real time river discharges information, forecasts
River plume	- coastal observatories, land surface and estuarine in situ observations - ferrybox + CTD casts, coastal observatories
Meso-/Submesoscale eddies	- SAR, SST. Ferrybox, glider, SKIM, drifters - Satellite SST, SSH, SLSTR, OLCI, SWOT, gliders, HF radar, altimeter

N. European Seas	Survey on observation and monitoring needs and requirements – EuroGOOS SAWG survey
Coastal-estuary continuum (BGC)	- SAR, Sentinel chl-a, river loads, in-situ chl-a, nutrients, ferrybox - coastal observatories, land surface and estuarine in situ observations - Nutrient fluxes from hydrological models
Algae bloom	- Dedicated field experiments for algae bloom process study - in situ BGC (incl nutrients), OLCI, Ocean colour daily, bio-Argo
Oxygen depletion	- Increased moorings with bottom DO measurements - satellite and in situ (profile) data, O2 measurments, Bio-ITPs
BGC-optical-SPM-physical interaction	- dedicated field experiments needed - in situ BGC and IOP observations, satellite optical parameters, Ocean colour daily, bio-Argo
Suspended sediment transport	- In -situ and satellite SPM Observation needed, near-bottom currents - SPM from Arctic rivers
Oil slick drift	- field experiments, drift/mixing measurements - Surface currents from space (SKIM)
Oil slick drift in icing waters	- Oil slicks in sea ice and below sea ice, ice drift
Microplastic drift	- Spatial-temporal observations - New monitoring data, source mapping, in-situ currents, drifters - field experiments on drift & biofouling experiment, data on distribution, hotspots, sources.
Macroplastic drift	
HNS drift	

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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 ares 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

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Thank you for your attention