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Baltic Sea Operational Oceanography System (BOOS) – a stimulant for Baltic Earth Science

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Contribution from other BOOS partners are acknowledged

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Operational oceanography (O.O.) in Baltic Sea

- **O.O.:** ocean observing, modelling and forecasting to provide operational services for
  - Forecast and and warning
  - Ocean Health
  - Climate change
  - Blue Growth sectors

- **Histry & future of oceanography**
  - Observing/Descriptive ocenography
  - Theoretical oceanography
  - Numerical oceanography
  - Operational oceanography
  - Earth system oceanography
  - Seamless oceanography

- **R&D activities are needed to**
  - Improve the quality of existing services
  - Develop new (forecasting) services

  by
  - Resolving current status of Baltic Sea via “optimal” monitoring network
  - Correctly resolving important natural processes, add them in operational models
  - Efficiently assimilating observations
  - Developing forecast technologies
- **Seamless service in future O.O.**
  - **Spatial**: estuary-coastal-open waters; surface-water column-seabed
  - **Temporal**: minutes to decades
  - **Parametric**: human pressure-physical-biogeochemical-food web-human impact

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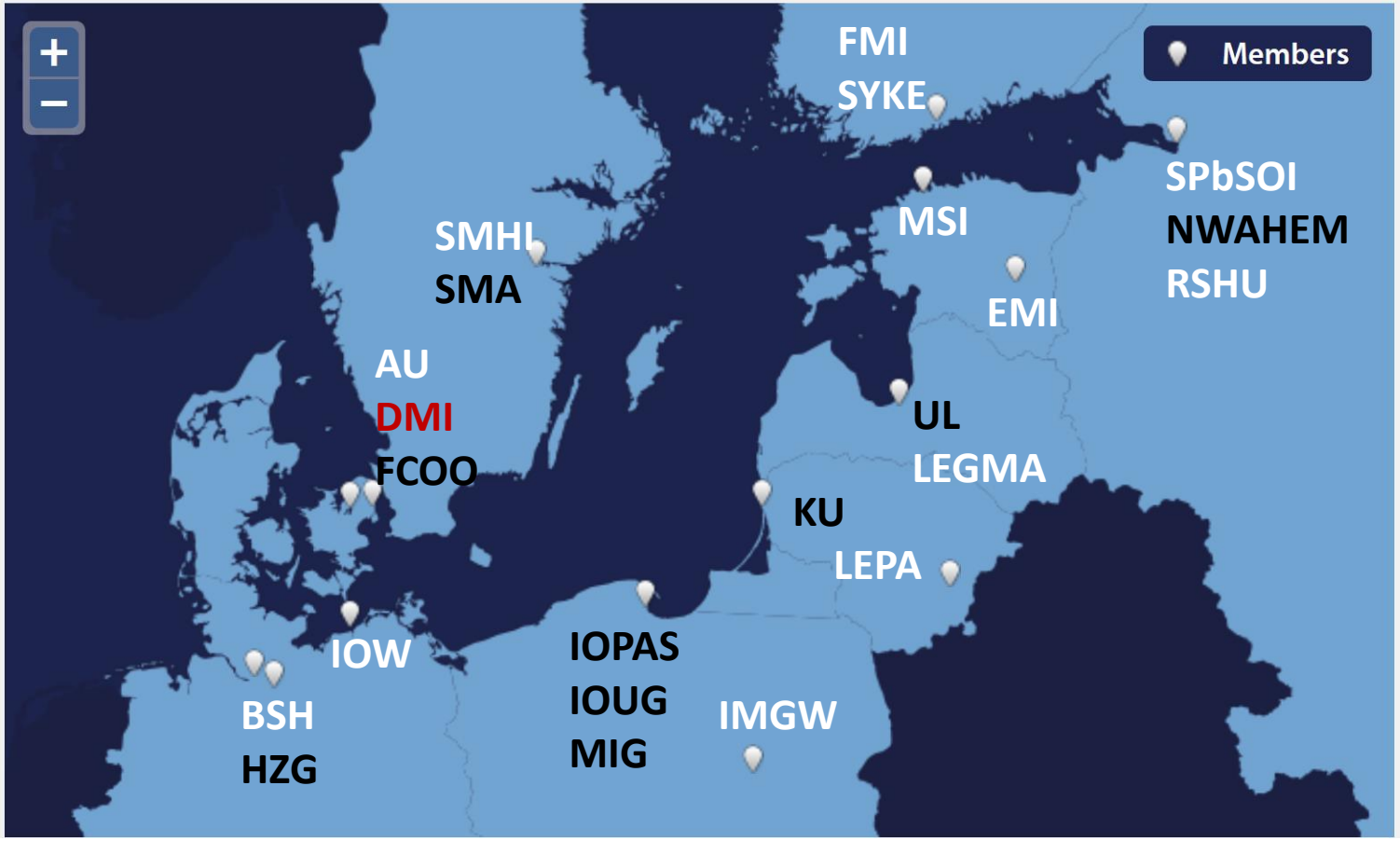
Members Map (23 members)



BOOS members are responsible for both operational and HELCOM environmental monitoring BSH, HZG, IOW, AU, DMI, FMI, SMHI, IOPAS, IMGW, KU, LEGMA, MSI, NWAHEM, RSHU also work on climate change study and service

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On-going BOOS Modelling activities

- **Collaborative Modelling**
  - **NEMO**: SMHI, BSH, DMI, FMI, MSI, (IOPAN)
  - **ERGOM:** BSH, IOW, DCE, MSI
  - **HBM:** BSH, DMI, MSI, FMI, UL, KU
  - **WAM:** FMI, BSH, DMI, MSI
  - **Cal/Val:** BSH, MSI, SMHI, DMI, FMI, FCOO, HZG, IOUG
  - **Multi-Model Ensemble:** BSH, FMI, DMI, SMHI, MSI, FCOO, IOPAN

- **National modelling activities**
  - **Ice Modelling**: SMHI, FMI, BSH, DMI, FMI, MSI, IOPAN, IMWG, FCOO, HZG
  - **Ecological modelling:** SMHI, IOPAN
  - **Ocean modelling:** IMGW (mike3), FCOO (GETM), HZG (NEMO, GETM, SCHSIM), IOW
  - **Wave modelling:** IOPAN, IMGW (shallow water), FCOO (WW3), IOUG, MIG
  - **Oil spill modelling:** BSH, DMI, SMHI, FMI, FCOO

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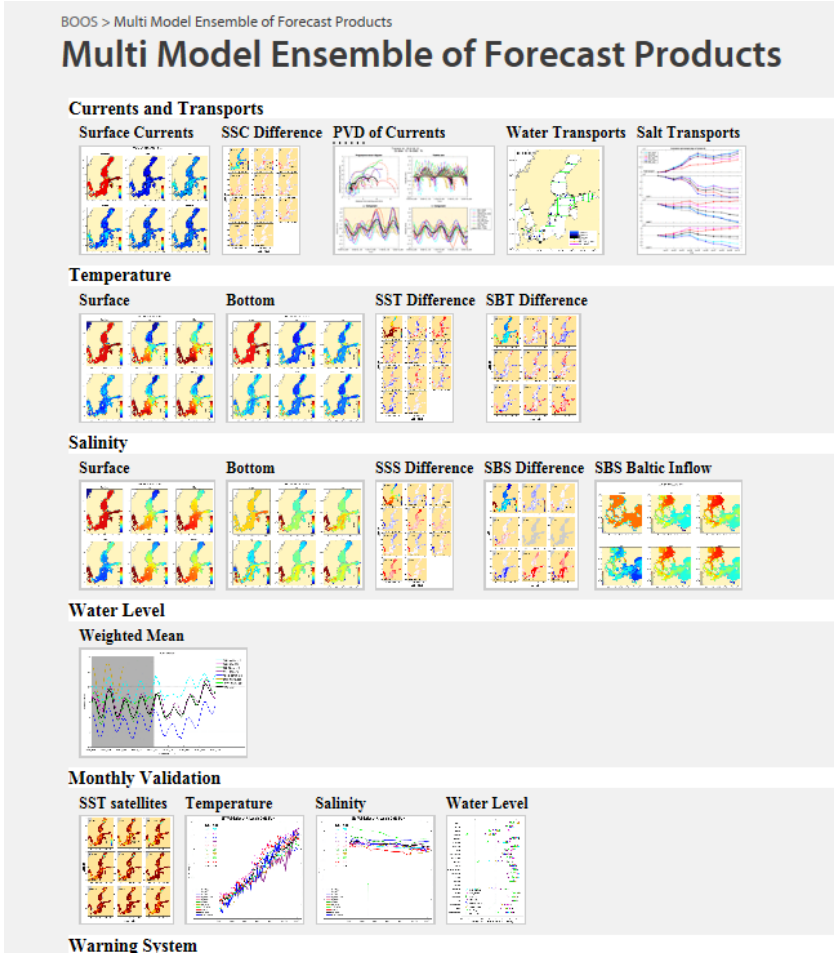
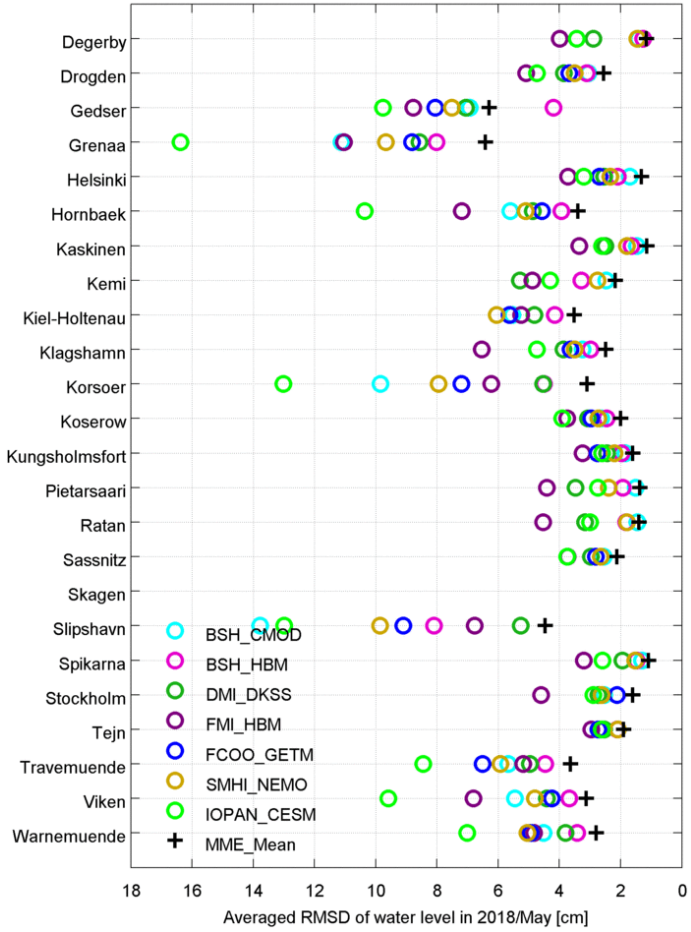
Multi-model ensemble forecast in BOOS





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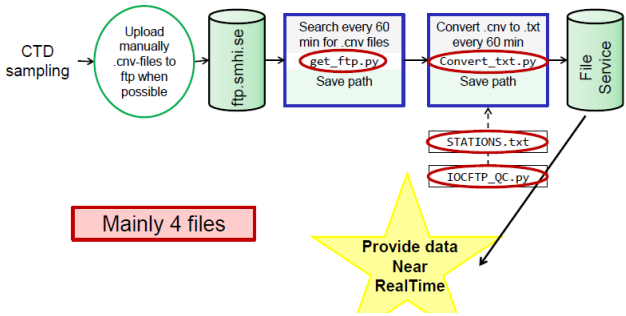
On-going BOOS Observation activities

- Data exchange: BOOS ftp network
- NRT ship data delivery TT
  - NRT ship data delivery workshop
- Observing system assessment and integration
  - She J. 2018, Assessment of Baltic Sea observations EuroGOOS conf. paper
  - She J. and J. Murawski: GEO Blue Planet special issue, submitted
  - BSCP Data adequacy report 2: fit-for-purpose assessment
  - Contribution to CMEMS in-situ assessment
  - Contribution to OceanObs19



	BSH	DMI	EPA	FMI	IOPAN	IOUG	IMGW	KU	MSI	SMA	SMHI	IOW	SYKE	RU	Total
TG	X	X	X	X			X		X	X	X	X		X	10
Argo	X			X	X						X			X	5
Buoy	X		X	X	X		X				X	x		X	8
RV	X		X	X	X	X	X	X			X	X	X	X	11
Glider				X					X						2
ADCP	X	X		X			X				X	x		X	7
FST	X	X	X	X		X	X				X	X	X	X	10
Ferrybox							X		X		X		X		4

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BOOS in-situ stations

http://www.boos.org

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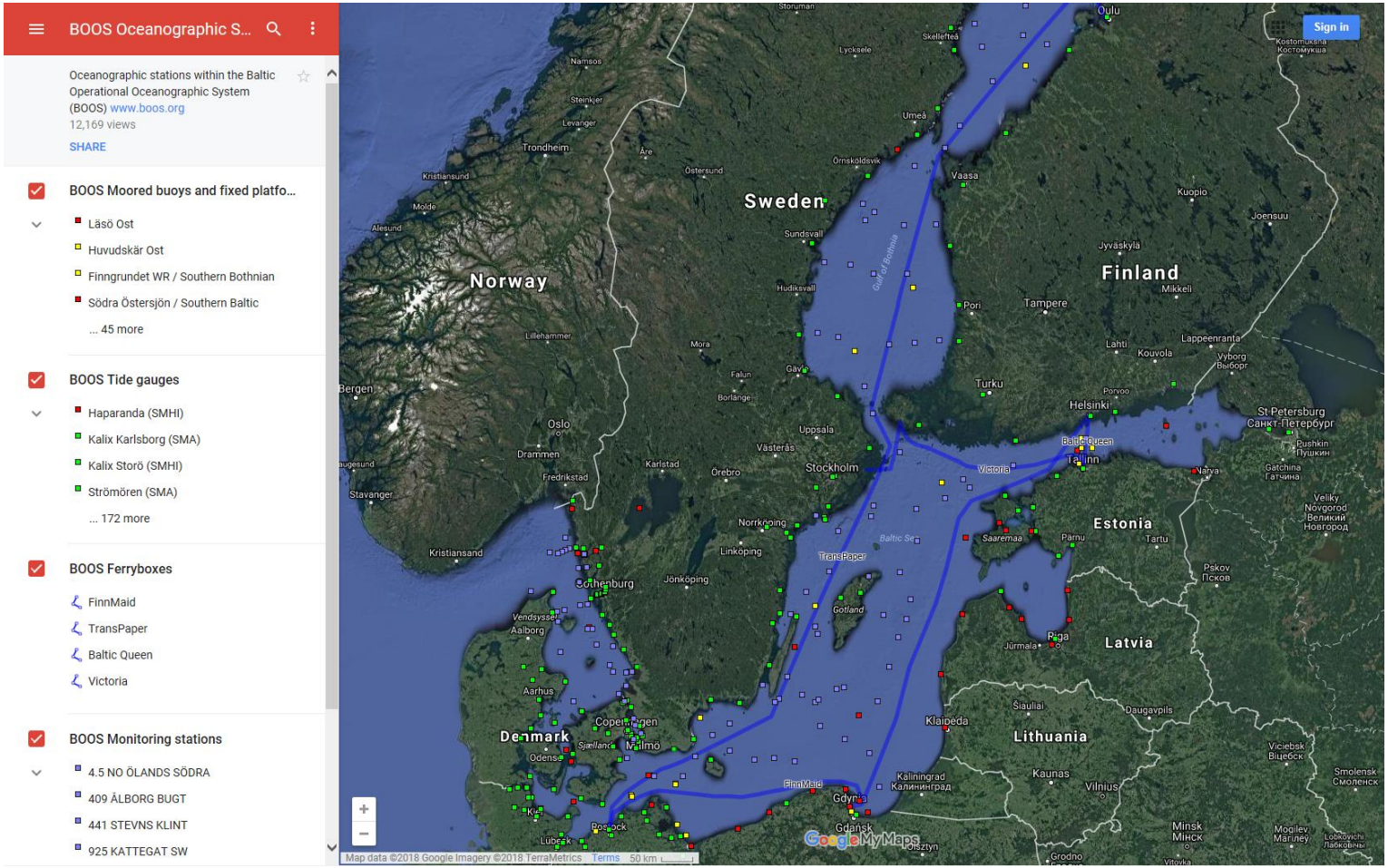

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On-going data assimilation activities

- **Existing schemes developed**
  - Multi-variate OI (SMHI, HZG, FMI)
  - 3DVAR, EnOI (DMI, SMHI, HZG)
  - EnVAR (SMHI)
  - LESTKF (BSH, DMI)
- **BOOS Data assimilation cooperation**
  - PDAF (Parallel Data Assimilation Framework) cooperation: DMI, BSH, SMHI, FMI, AWI, HZG
  - General cooperation: SMHI, BSH, DMI, FMI, HZG, AWI,…
- **Operational DA system**
  - NEMO-Nordic EnVAR
  - HBM Multi-variate OI
- **Opr. DA system in R&D**
  - PDAF-NEMO
  - PDAF-HBM
- **Physical-BGC reanalysis**
  - RCO-SCOBI: 1973-2000
  - NEMO-SCOBI: 1993-2016

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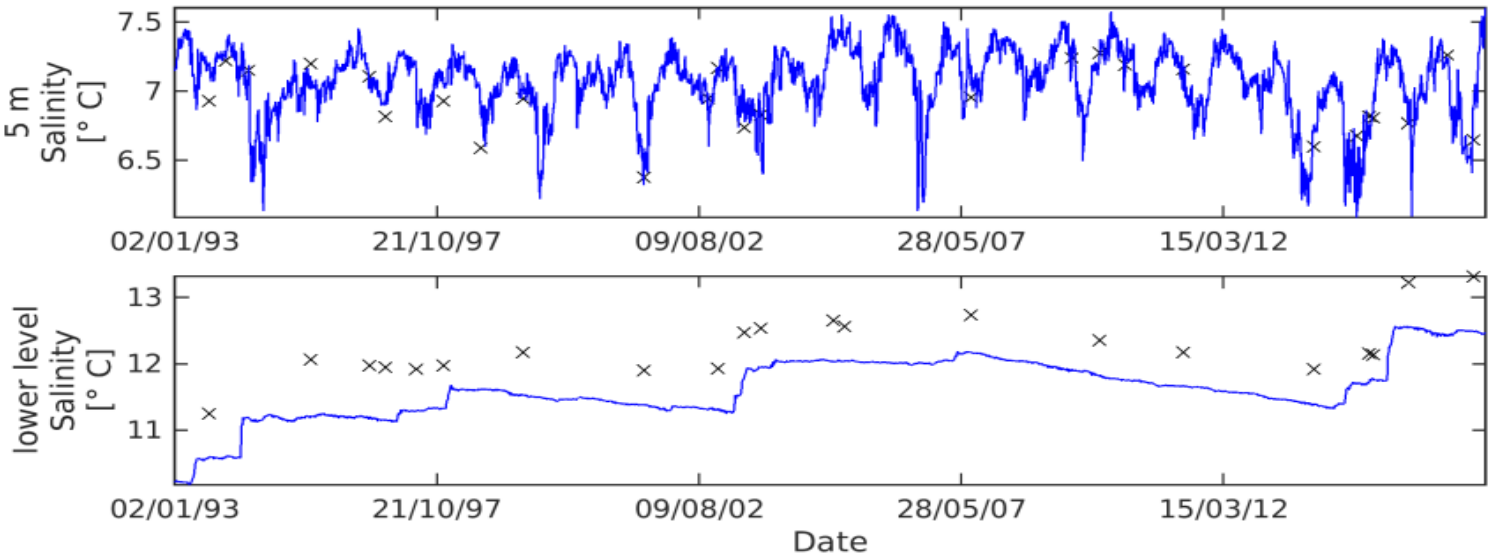
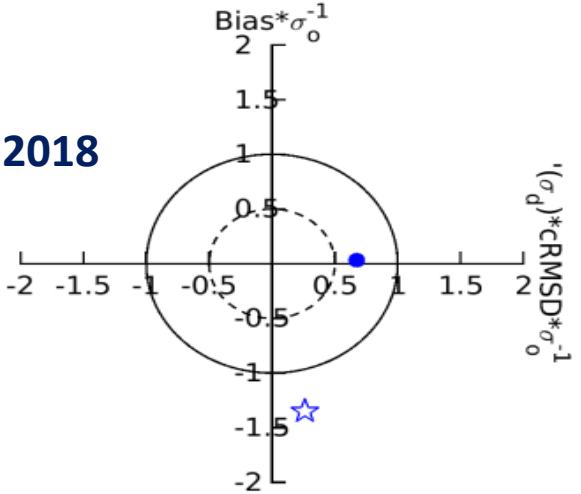
Reanalysis Validation at Gotland Deep



Courtesy of Ye Liu, SMHI, 2018

BMPJ1



• upper level
depth: 5 m
★ lower level
depth: 202 m

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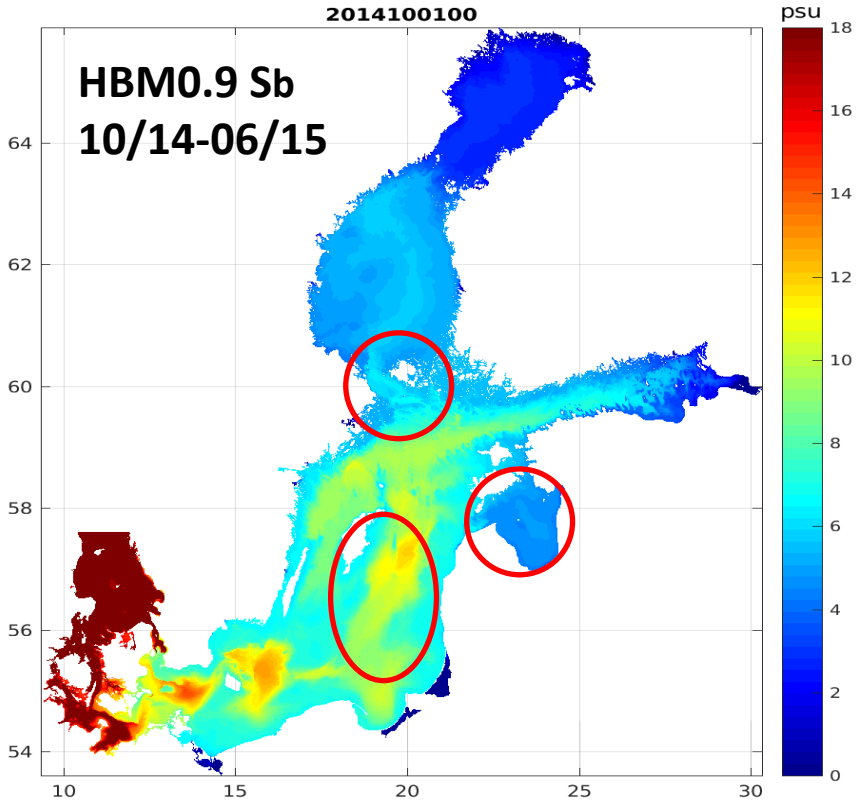
BOOS and Baltic Earth GC1: Salinity dynamics

- High resolution salinity observations:
  - Ferrybox, Argo and gliders
- Advanced modelling tools
  - Improved slope currents
  - Two-way nested Baltic-North Sea ocean-ice model
  - High resolution+HPC (sub-mesoscale resolving)
  - Coupling ocean-ice-waves
- Decadal reanalysis



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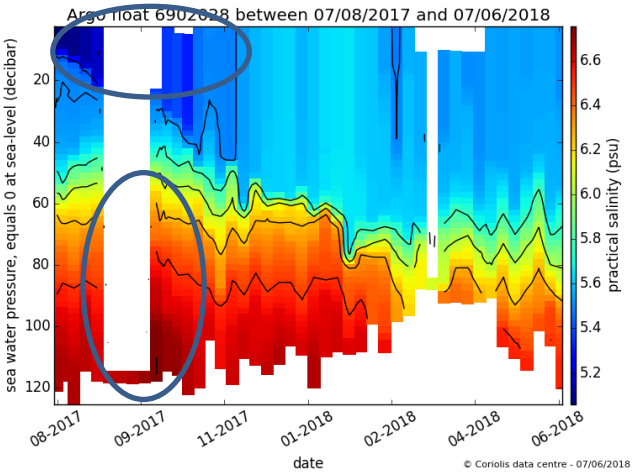
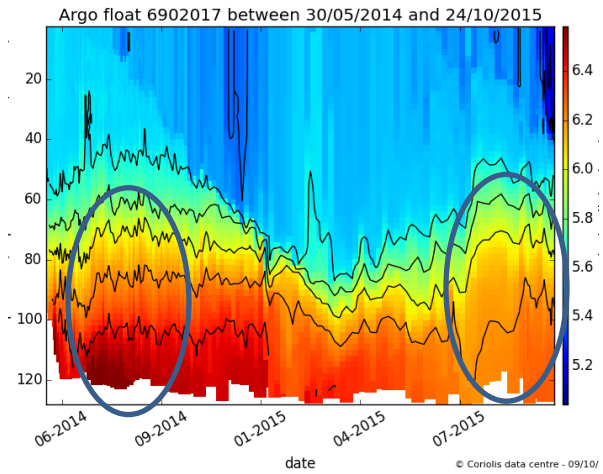
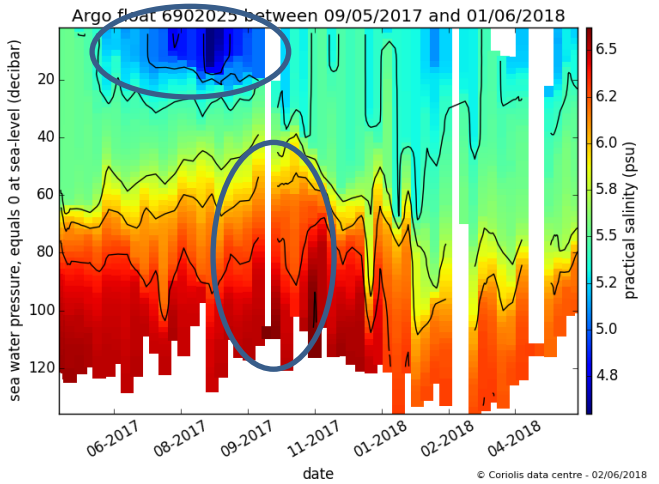
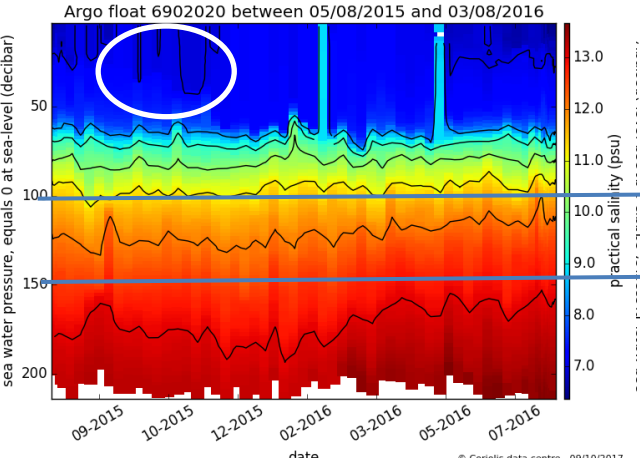
Messages from operational data: Argo floats in C. and S. Baltic Sea

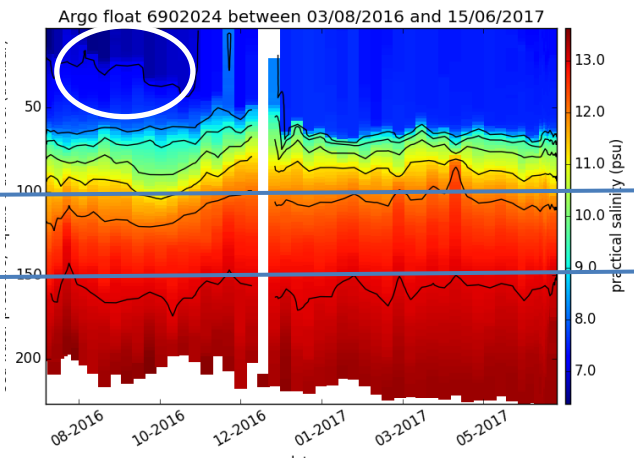
- Central Baltic: salinity below 100m has been increased since 2015.
- SSS: low in summer; Bottom salinity: High in ASO and low in FMA

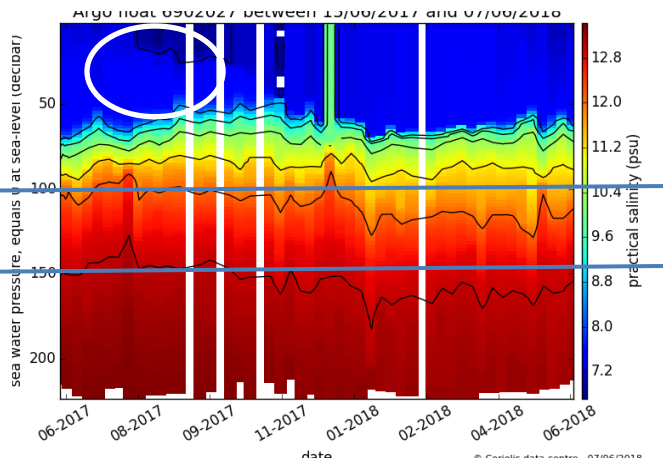






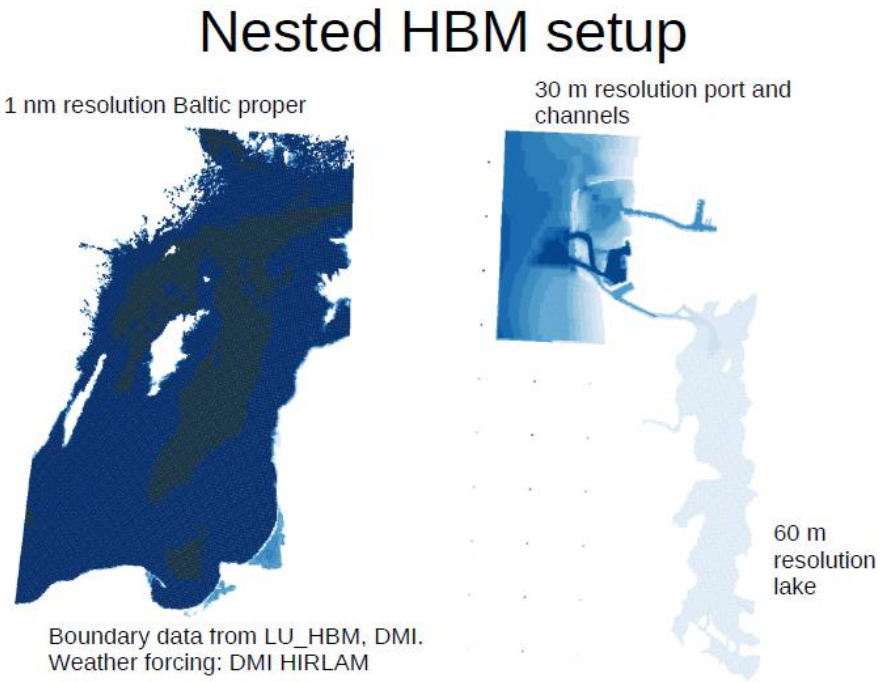






BOOS and Baltic Earth GC2: Land-Sea BGC linkages

- **Developing new forecast capacities in estuary-coastal continuum**
  - Physics: UL-HBM 20-60m grid, BSH-HBM: 90m grid; DMI-HBM: 185m grid; SMHI NEMO: 60m grid
  - Biogeochemical: DCE HBM-Flexsem, unstructured grid
  - Prediction of micro- and macroplastics drift: CLAIM
- **Monitoring:**
  - Ferrybox: T,S, DO, pH, Chl-a, Turbidity, diss.CO2, N, S, P, Ammonia, Yellow Substance etc.
  - Satellites: Sentinel 2,3: MSI, OLCI, SRAL for coastal chl-a, SSH; existing SST, Sea ice products in 1km resolution; CFOSAT for waves & winds, 70m resolution



(Courtesy: Frishfelds et al. 2018, UL)

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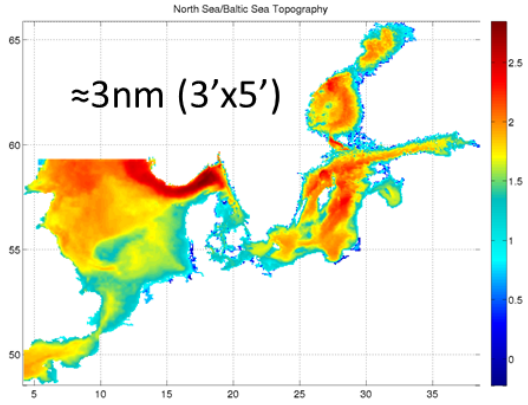
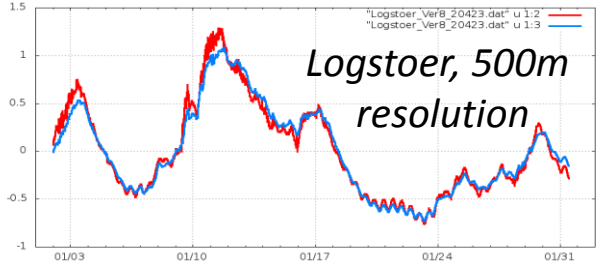
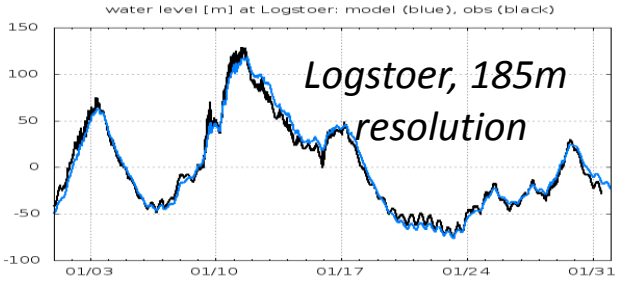
Seamless modelling: coastal-estuary continuum

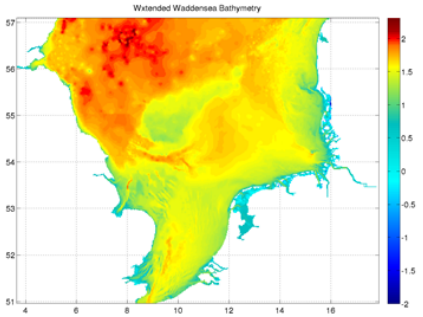
New DKSS Storm Surge Setup

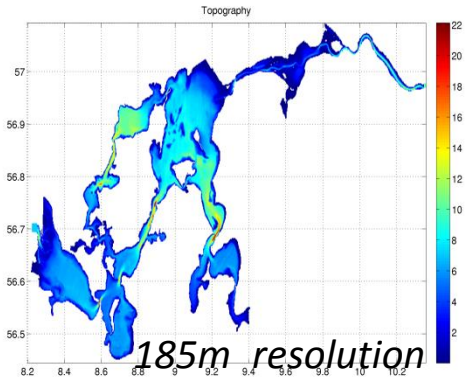




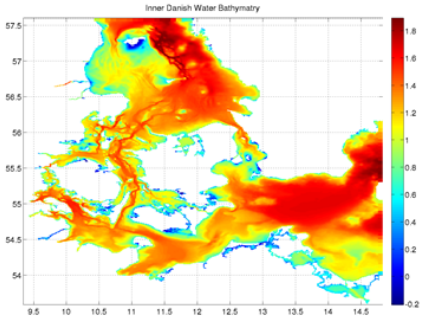


≈1nm (1'x1.66')





≈0.5nm (30''x50'')



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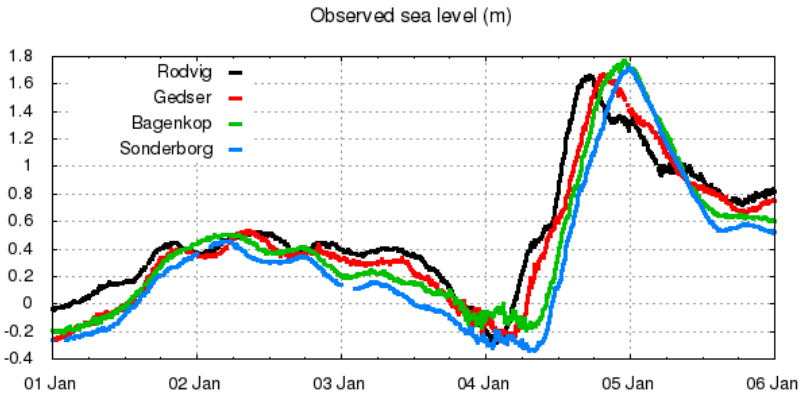
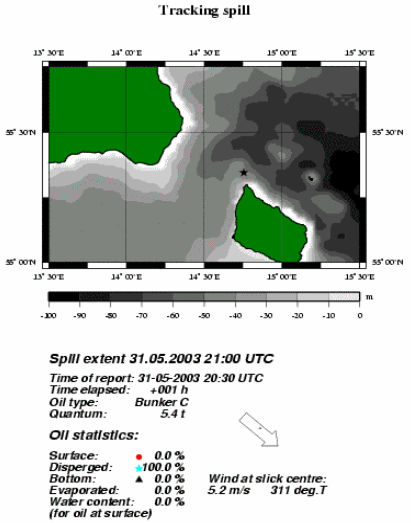
BOOS and Baltic Earth GC3: Natural hazards and extreme events

- BOOS develops calibrated, state-of-the-art models for
  - high wave modelling (with complex coastline, islands and in icing waters)
  - Storm surge modelling both in open coastline but also in estuary, port, lakes, etc.
  - Sea ice modelling
  - Oil drift modelling
- BOOS provides extreme events in Baltic Sea in Ocean State Report
- BOOS is developing forecasting capacity for
  - Skin temperature
  - Oxygen depletion
  - Algae bloom
  - Plastic litter drift forecast

”Silent” surge caused by remote winds





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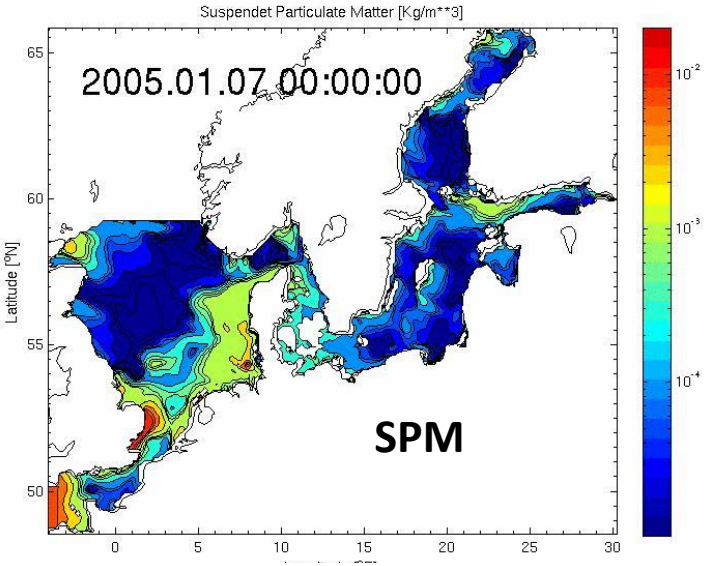
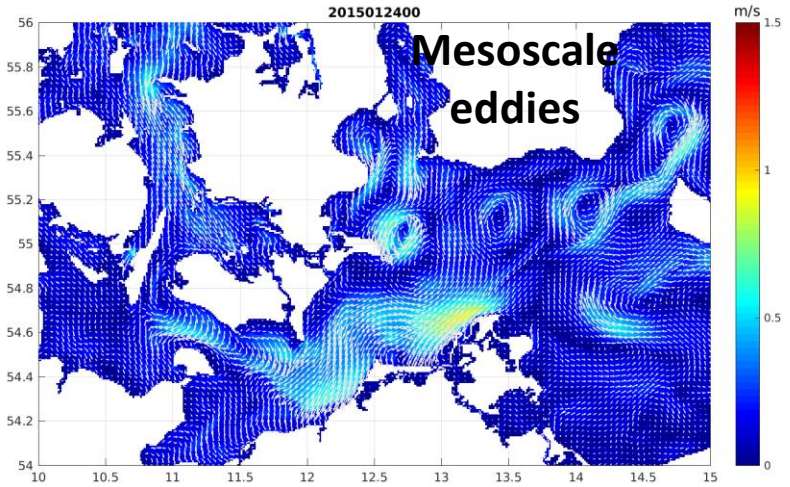
BOOS and Baltic Earth GC4+5: sea level dynamics and regional water and energy exchange

- BOOS is developing high resolution sea level product by assimilating satellite coastal SSH, tidal gauge stations into operational models
- BOOS is developing basin scale coupled ocean-ice-wave-BGC-assimilation system
- BOOS is developing submesoscale resolving and estury-port-lake resolving models





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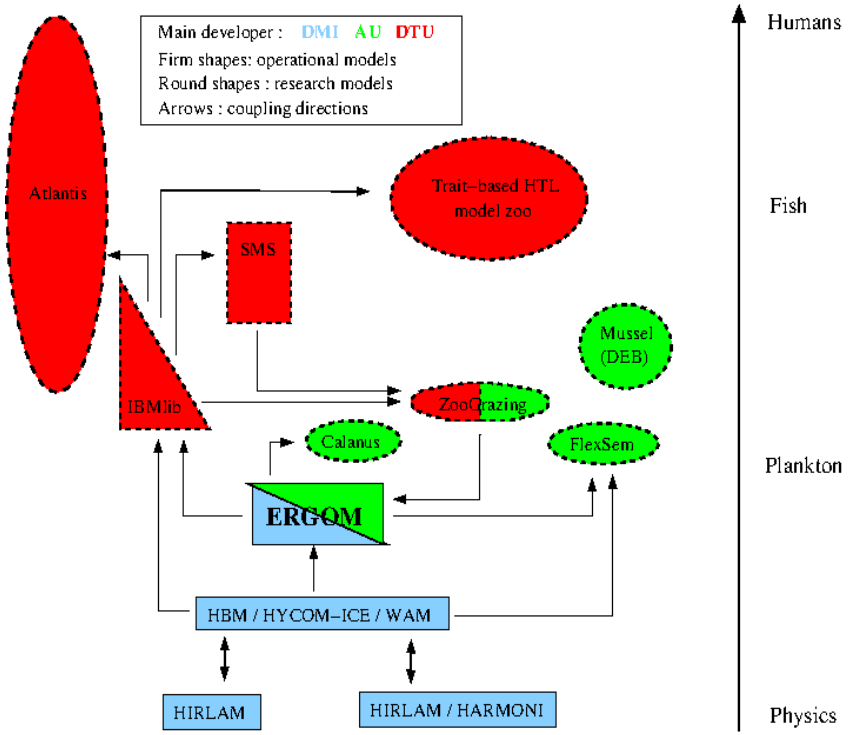
BOOS and Baltic Earth GC6: Multiple drivers for regional Earth system changes

- BOOS is developing operational ecology for esosystem-based management, e.g.
  - Seasonal forecast
  - Rapid Environment Assessment
  - Ocean monitoring index: tailored products
  - End2end modelling framewotk

End2end Modelling Framework in Denmark



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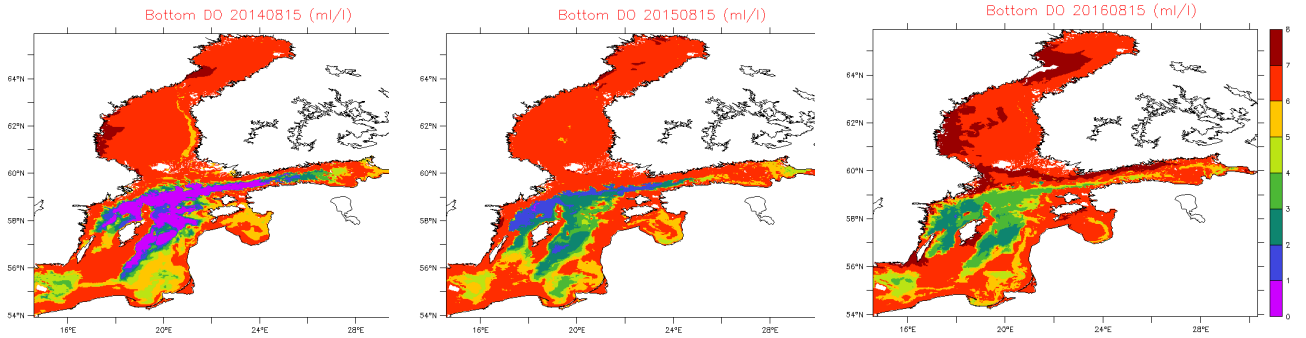
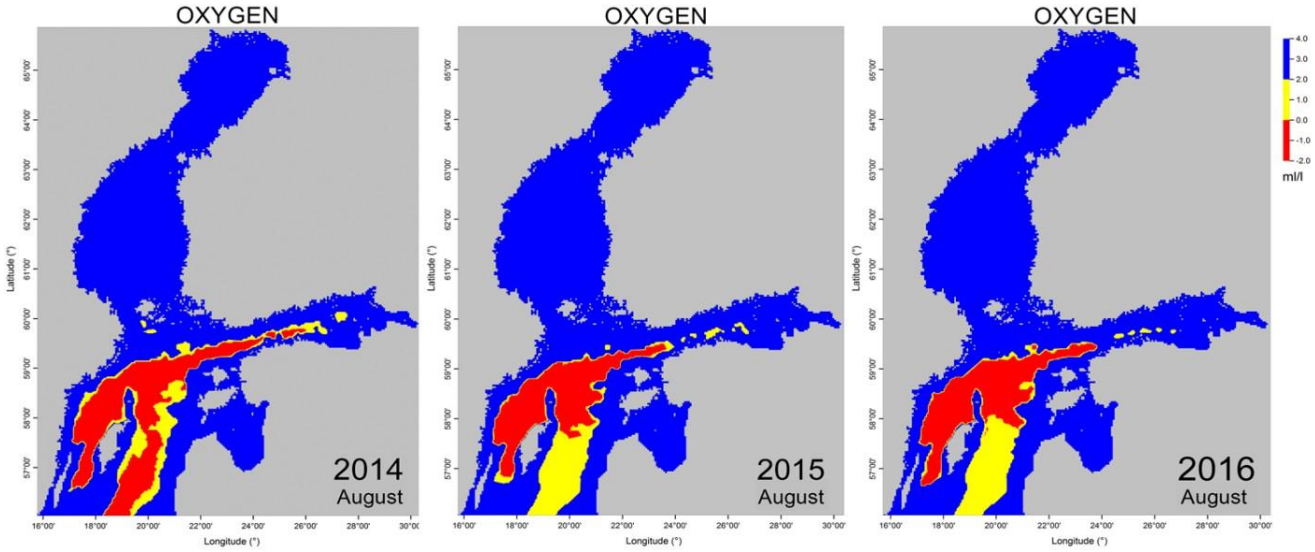
OSR Eutrophication 2016: bottom oxygen

Oxygen situation near the seabed in the Baltic Sea in 15 August 2014, 2015 and 2016, BAL MFC (ERGOM, 2014-16 8.15)



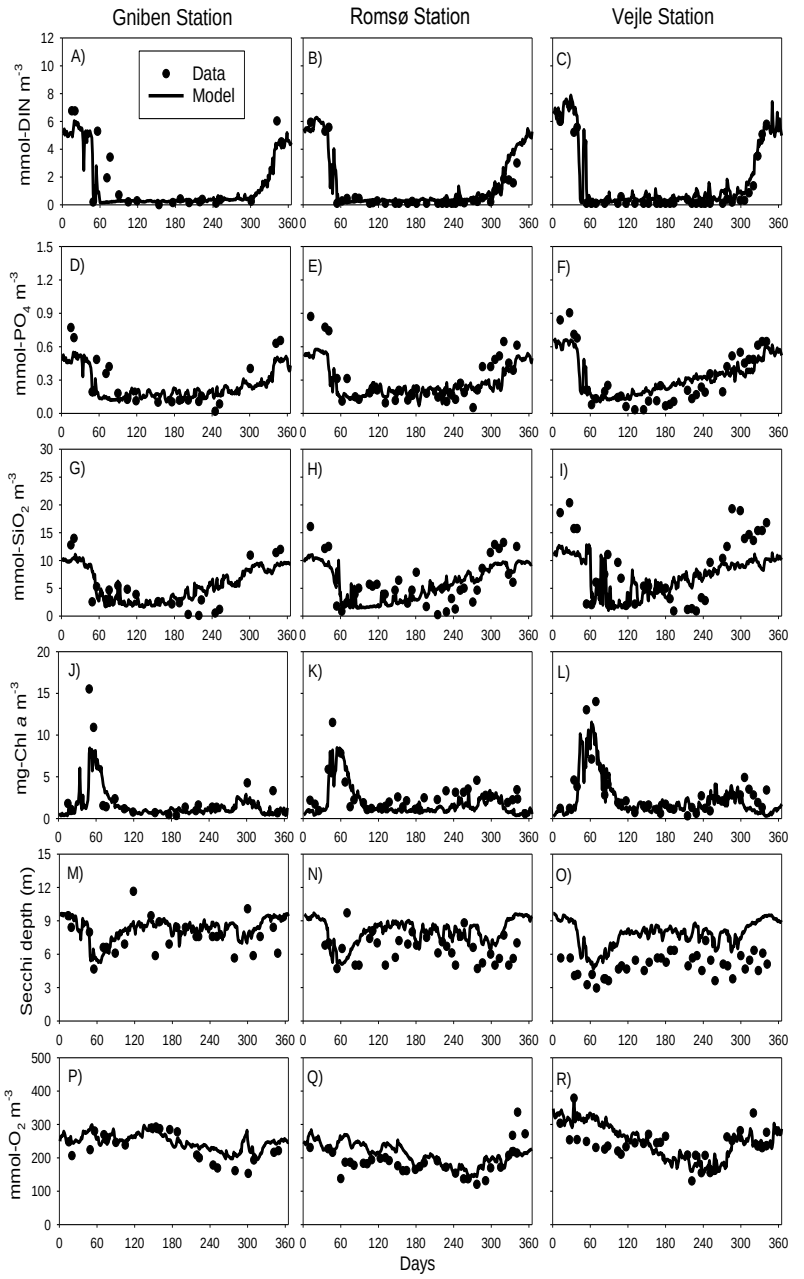
Oxygen situation near the seabed in the Baltic Sea in August 2014, 2015 and 2016 © SYKE (Observed, 2014/16 8.)



Validation of HBM-Flexsem model (courtesy of Marie Marr, 2018, DCE)

	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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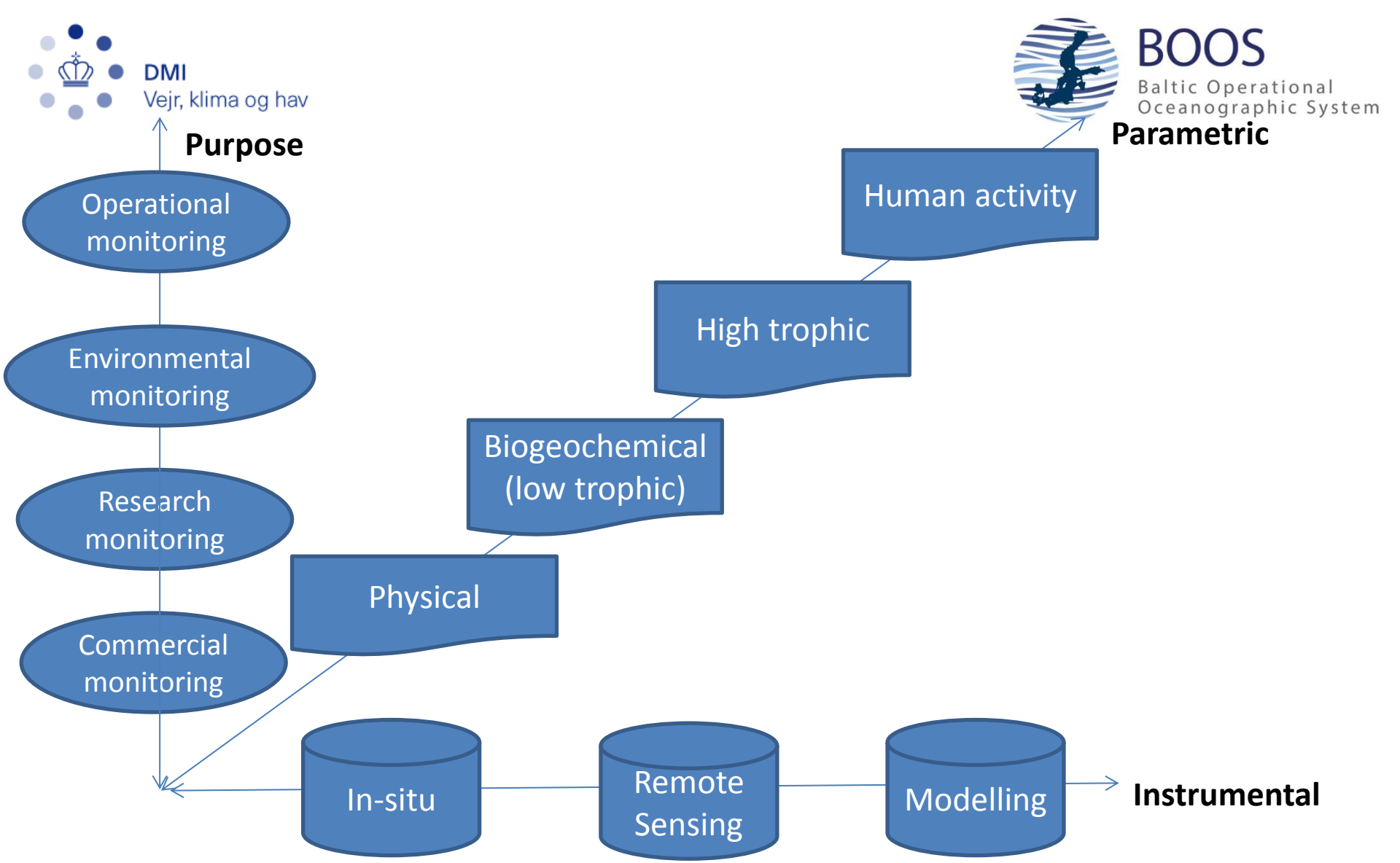
How can BOOS be benefited from Baltic Earth community?

- Research data sharing for operational use:
  - More open & free data
  - More NRT delivery
- Transfer of BEWG progresses into operational modelling platforms
- Joint proposals to cope with GCs through integrated monitoring-modelling approach
- Towards an integrated earth system oceanography and seamless service by breaking barriers



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

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Operational oceanography generates new challenges

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Danish Meteorological Institute

SST analysis from satellite observations
30 days back in time
Update: daily

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Parameter
Sea Surface temp (Anomalies)

Geographical domain
Global

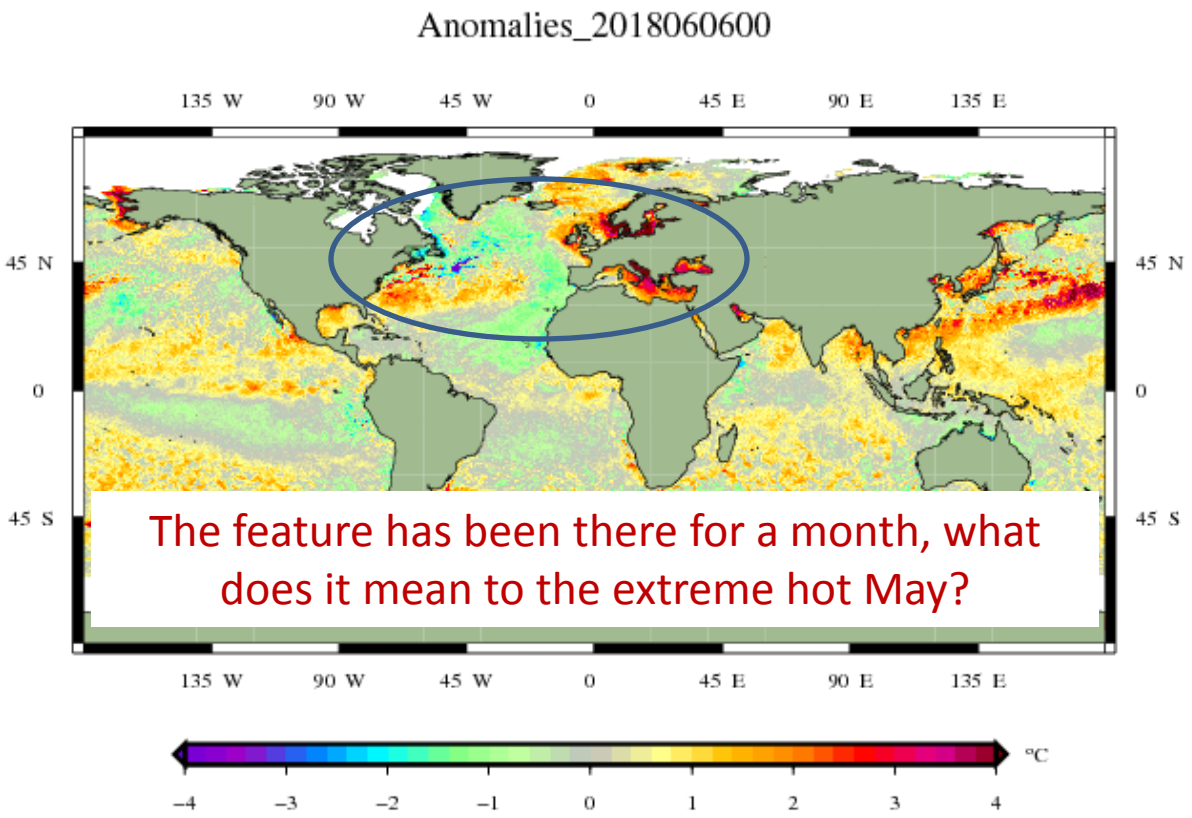
Time step
Today

Time stepping
|<< < > >>|

Animation
play loop stop
slower faster

Save my settings

howto data/method
mail us



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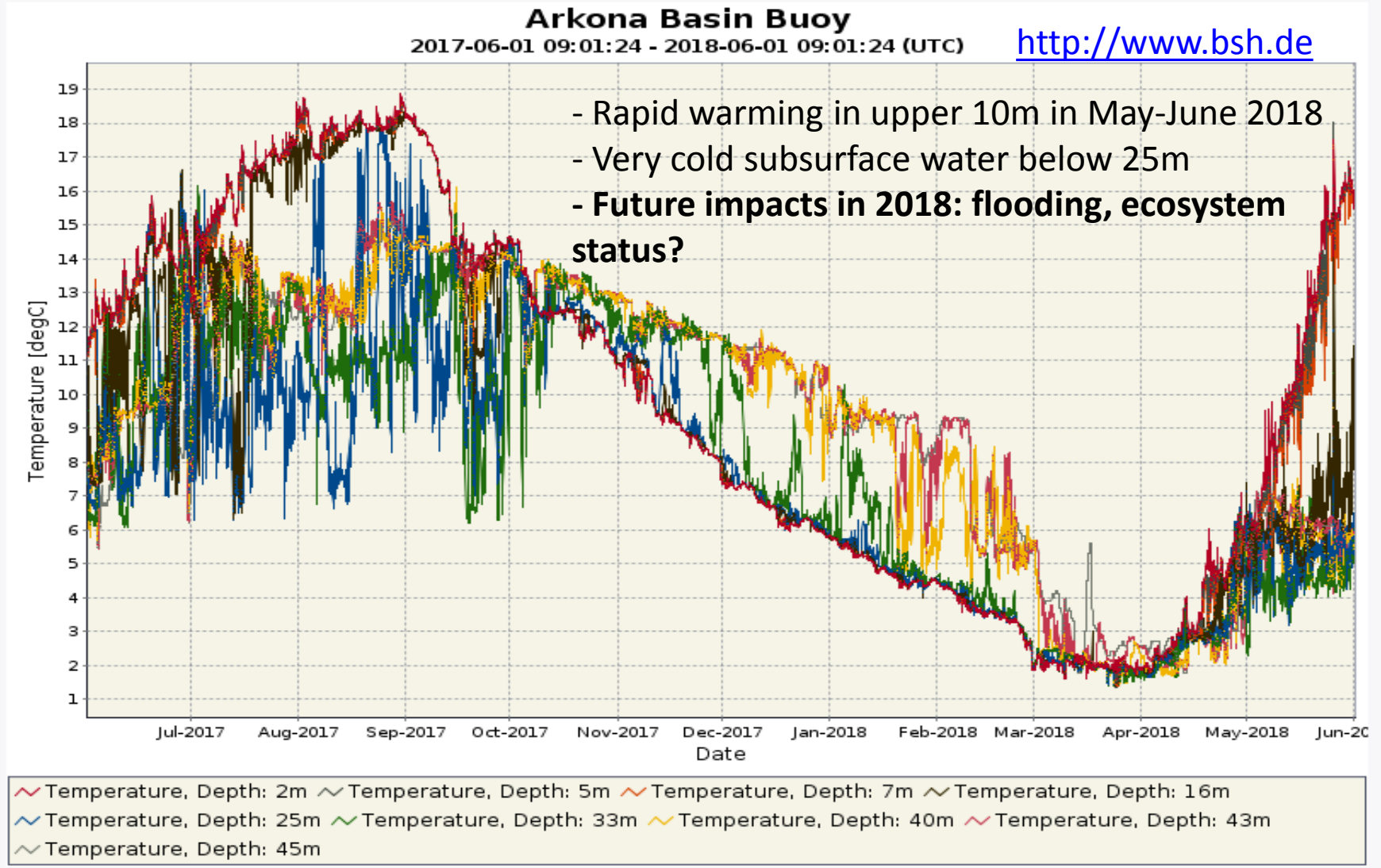
O.O. always generates new challenges



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Thank you for your time!