<u>Mo</u>dular <u>S</u>ystem for <u>S</u>helves and <u>Co</u>asts Synthesis

MOSSCO Synthesis

Proposal for a project in response to the BMBF call
Fortsetzung der Ausschreibung zur Küstenmeerforschung in Nord- und Ostsee
in the framework of Forschung für nachhaltige Entwicklungen (FONA-3)

Associated Partners:

Helmholtz-Zentrum Geesthacht, Institut für Küstenforschung (HZG)
Leibniz-Institut für Ostseeforschung Warnemünde (IOW)

Affiliated Partner:

Bundesanstalt für Wasserbau, Abteilung Wasserbau im Küstenbereich (BAW)

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Project duration: 3 years **Requested amount:** 638.031 EUR

BiB) Summary. Most challenges in coastal science and management demand an integrative approach. The project “Modular System for Shelves and Coasts” (MOSSCO) thus developed an infrastructure that facilitates integration of existing model and data components. In the second phase of the project (MOSSCO Synthesis) the modular infrastructure will be brought to a number of coastal applications, which are centered around the benthic-pelagic interface. High-resolution model studies will be conducted for four regions (southern North Sea, North Frisian North Sea, western Baltic Sea, and Oder Lagoon). Based on state-of-the-art hydrodynamical modeling, these applications will address research questions arising from the interplay of biogeochemical, ecological, and sedimentary processes within the coastal transition zone. Central questions focus on drivers of macrobenthic dynamics, the effects of macrobenthic communities on ecosystem and sediment dynamics, or an the processes responsible for nearshore nutrient gradients. Related model studies will support specific demands of partner KüNO projects including those in the engineering KüNO call, and of German authorities responsible for EU Framework Directives. “MOSSCO Synthesis” will produce estimates for the historical, present and future state of the coastal ecosystem, as well as for sedimentary states and budgets.

BIc) Project description

The project Modular System for Shelves and Coasts (MOSSCO) develops (1) **a concept** and an **open source software infrastructure** that facilitates the coupling of models and data sets for the coastal system and fosters the interdisciplinary cooperation between research groups, and (2) complete **applications** that investigate coastal system dynamics with a focus on both research questions (esp. this call: processes at the benthic-pelagic interface) and problems relevant to management and partner projects. The software infrastructure brings together existing models describing physical, chemical, geo-/ecological, and biogeochemical (BGC) processes; it facilitates the integration of novel process descriptions (e.g. benthic filtration) into a regional coastal Earth System context. MOSSCO is a community project bundling modelling expertise and efforts currently spread over institutions in Germany and worldwide.

MOSSCO Synthesis specifically generates model products in support of partner projects in the Küstenforschung Nordsee-Ostsee (KüNO) Synthesis consortium, associated international projects like BaltCoast and envisaged projects in the engineering KüNO call, and German authorities with a responsible role for executing the EU directives relevant to the coastal zone and adjacent shelf, the water framework directive (WFD) and the marine strategy framework directive (MSFD).

MOSSCO applications integrate modular process and domain models, tailored setups and input data relevant for addressing specific research questions. We will build applications for the Southern North Sea (SNS) and the Western Baltic Sea (WBS), and, nested therein, for the North Frisian North Sea (NFNS) and the Western Oder Lagoon. Each of these regional applications will share a basic set of data and models but will be customised differently: (1) the SNS and WBS applications will resolve lateral material fluxes and benthic nutrient cycling to achieve first nutrient and sediment budgets and to elaborate improved indicators and regionalisations for water quality management as guided by the WFD and MSFD; (2) the NFNS application will be centered around a novel macrofauna module that will help to investigate the influence of organisms at the benthic-pelagic interface on coastal BGC and sediment dynamics and, vice versa, the effect of anthropogenic disturbances on macrobenthic dynamics; (3) the Oder Lagoon application implements a suspension feeding module for evaluating planned "building-with-nature" actions for water quality restoration.

B1d) Objectives

Main objectives

The overarching goal of the project "Modular System for Shelves and Coasts" (MOSSCO) is to develop further and to apply a new concept of modular knowledge integration of model and data components and to demonstrate its usefulness in applied and fundamental research. In the synthesis phase, the MOSSCO infrastructure addresses specific research questions or management needs such as nutrient budgets and their sensitivity to natural and anthropogenic factors. With the selection of four applications the project will strategically fill a gap in marine research, because the transition zone between estuarine and shallow waters and the shelf is rarely studied at sufficient process depth and numerical resolution.

Envisaged model products meet the demands of associated projects or joint activities in the KüNO Synthesis call, generally consisting of high-resolution estimates of physical and BGC states. Furthermore we seek to continue our model-based investigation on the two-way interaction between ecology and sediment dynamics in nearshore systems. Potentially critical process relations at the benthic-pelagic interface will be studied and their relative contribution to sediment and element fluxes quantified. We thereby follow the process cycle "suspension feeding → primary production → particle settling → macrofauna dynamics" that encompasses functional compartments located along the benthic-pelagic continuum from the upper 20 cm of the seafloor to surface waters. We aim at a more integral view of the coastal (material) system, while highlighting the role of macrobenthic living. Therefore, trait-based models of the macrobenthic community will be devised. We will further investigate to what extent benthic ecology influences particle transport in near-coast systems, and to what extent the complexity inherent to water quality changes can be reduced to simple, cost-effective observational proxies such as water transparency or oxygen concentration. MOSSCO supports authorities in their evaluation of, e.g., water quality or sediment stability for the WFD and MSFD.

Goals of partners

An intense collaboration of the partners has been established in phase 1 for accomplishing the successful development of a highly complex infrastructure and for conducting integrative studies. We seek to maintain this synergy in the synthesis phase such that major goals and tasks of the three partners remain consistent with those of the coordinated project, however with different weighting. HZG ensures the operability of the framework infrastructure. By providing accurate hydrodynamic models and setups IOW (Burchard) leads the implementation of the coastal applications, while BAW focuses on sediment dynamics and HZG on ecological and biogeochemical aspects. Each partner is responsible for applying a coastal setup in a specific research and management context. IOW (Schernewski) and HZG continue to transfer model results to MSFD/WFD implementation.

Relevance for the call

MOSSCO has been built in direct response to the first KüNO call as part of the BMBF Framework Programme "Research for Sustainable Development" (FONA), in particular addressing the central demand for "modular model systems". MOSSCO introduces an open communication standard that facilitates the exchange of models, data sets, and expertise across disciplines and institutions, including coastal engineering. Usage of a common standard of Earth System model coupling prepares the interaction with regional climate models in order to better resolve climate change impacts on the coastal ocean (cf. item 1 of the 1st KüNO call). Our high level integration of models and data, and subsequent simulation analysis lays a "basis for an improved understanding of coastal ecosystems" (item 2.1). All proposed applications investigate "interactions, exchange and transport processes between sediment and water column" (2.2). New fundamental insights are expected from our integrative analysis of the interplay between macrofauna, sediment, and primary producers at this interface. From a research perspective, MOSSCO itself is an "innovative infrastructure and system in the coastal zone" (2.3); the project directly evaluates how artificial structures improve water quality in the Oder Lagoon as inspired by the eco-engineering concept of "building with nature".

MOSSCO Synthesis fully fits into FONA-3, chapter 3.2 (sustainable resource usages) and 3.3. (protection of marine areas and biodiversity). Our applications and model-based products address central demands of the FONA guidelines for supporting the assessment and maintenance of ecosystem services, and the implementation of an integrative and sustainable marine policy. In the very spirit of the 2nd KüNO call, the project continues to transfer knowledge from natural sciences to coastal management and engineering, here with the focus on sediment dynamics.

Model products will be made available as interactive maps through a web-based geographic information system (WebGIS, www.mossco.de/webgis). These maps and the underlying modeling will help to evaluate the coexistence of marine protected areas and human usages such as fisheries, offshore wind farms, or sediment dredging. The project is intensely networked with the following institutions and projects/research programs:

Institution/Project	**MOSSCO services and products**
PACES (Topic 2)	Basis for long-term (60yr) SNS simulation
BSH	River forcing data, retention scenarios
UBA, NLWKN LLUR, LUNG	State estimation for WFD/MSFD definitions, evaluation of indicators and proxies, past/future scenarios, harmonisation Baltic-North Sea
KüNO partners	Customized applications SECOS: WBS, physics-macrofauna; NOAH: SNS, BGC, STopP: NFNS physics-predators; BACOSA: SNS/WBS, ecosystem states.
TROPOS	Component coupling (atmosphere-ocean) (LOCUS)
BONUS	Joint modeling: impacts of eco-engineering measures (BaltCoast)

In an associated proposal led by coastal engineers (TU Harburg), MOSSCO with its modularity will be proposed to act as a linking unit between separate model suites used in the fundamental and applied branches of coastal research. Also other proposals under preparation (led by U Hamburg, U Hannover) for the coastal engineering KüNO call intend to use the MOSSCO infrastructure.

BIe) State of the art

Shelf and coastal seas embrace most relevant interfaces of regional Earth Systems. They mediate strong interactions between atmosphere, open ocean, geosphere and anthroposphere. An understanding of coastal seas requires approaches across disciplines, and across Earth System compartments, which was already recognized for the North and Baltic Sea areas in the 80ties and 90ties by research programs such as BASYS, GLOBEC, or BALTEX. These regional northern seas are therefore among the best studied worldwide, also with respect to the diversity of coupled models (e.g., MIRO, BALTIMOS, ECOHAM, ERGOM, BALTSEM, SCOBI, ERSEM variants, or ECOSMO). One of the few coastal modelling systems that spatially extend from the atmosphere into the sediment is COAWST (Warner et al. 2010). Regional coupled model systems, however, including the partially modular COAWST system, offer low flexibility in adding or exchanging process descriptions within individual domains because monolithic structures make it difficult to include modules developed elsewhere, or to conduct model intercomparison studies.

Modular coupling between Earth System domains is typical for current coupled model initiatives worldwide: the ocean and atmosphere components are run via a coupling library, like MCT or the Earth System modelling Framework. The number of modularly coupled components is two to four, at maximum. All processes within the ocean or atmosphere domain, however, are then internally hardwired, e.g. plankton ecology with the ocean physics. A different granularity is achieved by the Modular Earth System (MESSy, Baumgärtner et al. 2015), where each (atmospheric) process is represented as an independent component, and all processes are then assembled into a coupled system. While MESSy complies with a general trend in software architecture to divide complex systems into components with clearly defined interfaces, it lacks the flexibility to include existing software (other atmospheric models) without a large effort.

In coastal research, lacking modularity and resulting incomplete process descriptions become particularly apparent for suspended particulate matter (SPM). Transport of SPM in coastal seas does not only depend on geomorphological characteristics of the seafloor, but also on tidal and residual currents, water turbulence and wave statistics (Van Rijn et al., 2013, Kösters and Winter, 2014). Therefore, the simulation of SPM requires an accurate physical forcing, which can only be provided by state-of-the-art hydrodynamical models including wave-current and wave-turbulence coupling. Furthermore, resuspension, deposition and removal are critically affected by biological parameters such as macrofauna abundance and activity (van Colen et al. 2014), microbial stabilisation of the upper sediment layer (Fang et al. 2014), filtering by mussels, or by (dis)aggregation of particles depending on their stickiness due to exopolymers (Maerz & Wirtz 2009). Still, the description of SPM dynamics in biogeochemical models is often simplistic (van der Molen et al. 2009) so that biological factors are usually neglected in SPM modelling, which challenges both basic research and management applications (Winterwerp & van Kesteren 2004).

Absence of modular coupling also reduces the quality of ecosystem state estimates since suspended particles and aggregates largely impact coastal primary and secondary production. SPM not only controls underwater light climate, but also acts as carrier for organic material. Conceptual model studies (e.g., Ebenhöh et al. 2004) indicate that asymmetric tidal transport of particulate organic material is likely the main driver of coastal gradients in N- and P-levels, and their regional differences. This is in agreement with model results of Burchard et al. (2008, 2013) which reveal sediment accumulation by density-driven estuarine circulation and tidal pumping in the near-coast zone. Recent findings based on Scanfish data in addition point to an enhancement of SPM settling in the coastal transition zone, which together with the above-mentioned mechanisms would promote the accumulation of organic and inorganic material in near-coast waters (März et al, subm.).

A central but also poorly considered agent of both ecosystem and sediment dynamics, and of their mutual interplay, is the macrobenthic community. Epifauna and infauna mediate vertical particle fluxes through suspension filtering, sediment (de)stabilisation, and bioturbation. Existing dynamic model formulations for benthic macrofauna, in particular mussels, concentrate on food availability as major growth factor (e.g., Kitazawa et al. 2008). Physiology and growth of benthic fauna has been formulated within Dynamic Energy Budget Theory (Maar et al. 2010). However, these (dynamic) approaches neglect relevant factors governing the spatial distribution of macrobenthos abundance and composition (e.g., suspension vs. deposition feeders) such as mortality by toppredators and, above all, grain size. The limited attention of shelf- and coastal ecosystem modelling paid to the sedimentary composition of the sea floor comes along the neglected link to SPM dynamics. Correlations between factors such as grain size and the distribution of macrobenthic species are increasingly calculated using statistical models (Reiss et al 2014). While this approach enables to generate spatial maps, it ignores the time dimension of macrobenthic activity and community composition. It thus remains to integrate the macrobenthic reaction to time-variable drivers and disturbances into the model description of ecosystem and/or sediment dynamics. As a consequence, the influence of macrobenthic activity (bioturbation) and community composition on benthic-pelagic fluxes of dissolved compounds and benthic diagenesis is poorly addressed for coastal and shelf systems, where only first and partially empirical modelling approaches have been tested so far (Provoost et al. 2013, Capet 2014). This adds to the uncertainty especially arising from benthic remineralisation processes, that limits our ability for accurate nutrient budgeting as needed for water quality management. Benthic diagenesis models applied to coastal sediments such as the ERSEM module (Ruardij & van Raaphorst (1995), OMEXDIA (Soetaert & Middelburg 2009) or ECO (Smits & van Beek 2013) were until now not linked to high-resolution descriptions of macrobenthic variability; coupled benthic-pelagic models have become more testable through increasing availability of data such as on spatio-temporal variability in denitrification (e.g., Bonaglia et al. 2014, NOAH/SECOS).

Water quality and eutrophication status of marine ecosystems is often determined via supporting parameters, like Chl-a or nutrients and (“intercalibrated”) threshold concentrations. These values were recently derived for the WBS based on present observations and simulated changes for present and historical nutrient loads (the latter representing the pre-industrial situation of 1880, Schernewski et al. 2015). However, this indirect method needs to be improved towards a more direct water quality indicator such as transparency, which includes all aspects of eutrophication, like phytoplankton blooms, sediment resuspension, and growing conditions of submerse macrophytes. Water transparency has been historically recorded (e.g. Oder Lagoon, Brandt 1894) and is strongly linked to ecosystem services (Friedland et al. 2015). The derived water quality targets should be harmonized for coastal waters and open seas, and it needs to be tested whether the methodology can be applied to the SNS. For this area, only rough thresholds defining the Good Ecosystem State (GES) exist so that a recently established working group of state and regional authorities (e.g., UBA, NLWKN) and HZG discusses novel approaches to adjust thresholds and targets.

B1f) Own preparatory work

HZG successfully built the coastal observatory COSYNA[1] as a large-scale community infrastructure such that validation data for the reference decade 2003-2013 is available from many platforms (FerryBox, ScanFish, MERIS) and many parameters for water quality (e.g. SPM, Chl-a, nutrients, O2). HZG operates the CoastDat repository, where atmospheric and oceanic long-term simulations of the physical state of the German Bight are publicly provided for the period 1948 to present. Updated simulation results (CoastDat2) have recently been produced at HZG and will be used as physical forcing data. K. Wirtz and his group have applied complex and simple coupled 3D

[1] Coastal Observatory for Northern and Arctic Seas

models to explain ecosystem dynamics in the SNS, also focussing on the role of SPM (Tian et al. 2009). Current studies address adaptation processes in the plankton employing the expanded novel ecosystem model MAECS[2]; MAECS has been implemented in FABM[3], as was the benthic diagenetic model OMEXDIA (Soetaert & Winterwerp 2009) enhanced with a P cycle (Hofmeister 2014 et al.). K. Wirtz (co-)developed a model for SPM aggregation (Maerz & Wirtz 2009) and economic evaluation schemes for linking GIS data and models to problems of coastal management (e.g., Wirtz et al. 2007).

IOW has a broad experience in the development of hydrodynamic and biogeochemical modules such as GOTM[4], GETM[5] or ERGOM. Physical model applications extend from small scale coastal applications such as for the Wadden Sea (Burchard et al. 2008; Purkiani et al. 2015) to basin-wide climate downscaling simulations (e.g., Gräwe et al. 2015). The dependence of coastal sediment transport and morphological changes on (physical) drivers had been studied, e.g., within the PACE project. IOW validated a 3D model for the Oder estuary and calculated the cost effectiveness of mussel-farming as nutrient retention measure by linking economic approaches to an ecosystem model (Schernewski et al. 2012). Costs of changes in simulated denitrification rates for selected Baltic Sea rivers were calculated using cost avoidance principles (Allin et al., submitted). IOW is coordinating the BONUS-project BaltCoast, in which a systematic management approach for different human activities is developed within the Systems Approach Framework. A central study addresses the use of eco-technologies to decrease eutrophication within the Oder Lagoon. On behalf of the Federal Maritime and Hydrographic Agency, IOW is conducting the German contribution to the monitoring of the Baltic marine environment in the framework of the Helsinki agreement (HELCOM). These data are available for the validation of MOSSCO modules as the data from the three MARNET-stations operated by IOW. Within MOSSCO-1, a state-of-the-art wave-current coupling based on the latest 3D Radiation Stress formulation (Moghimi et al. 2013, Mellor 2015) has been implemented into GETM. ERGOM has been cast to FABM for interactive coupling.

The hydraulic engineering branch of BAW provides decision-making support for technical, economic and ecological questions in all German inland and coastal areas. BAW runs 3D hydro- and morphodynamic models for the North and Baltic Sea and the German estuaries. For the German Bight, they investigated the relative contribution of tides, wind and waves on sediment transport and morphological changes (Kösters & Winter 2014). For the Weser estuary BAW operates a sediment transport model to assess the impact of hydrological boundary conditions on sediment transport (Kösters et al. 2014). These systems were also employed in previous research projects such as KLIWAS or AufMod. Within AufMod, a consistent data base of the topography and sedimentology of the German Bight has been developed and made publicly available. BAW has successfully coupled models for hydrodynamics, waves, and morphodynamic in order to analyze the large-scale sediment transport and the morphological evolution of the German Bight (e.g. Plüß and Kösters, 2014). Delft3d geology modules (sedimentation and erosion) have been integrated into the MOSSCO system. Macrofauna and microphytobenthos effects on the sediment transport

[2] Model for Adaptive Ecosystem in Coastal Seas (Wirtz & Pahlow, 2010; Wirtz, 2013)
[3] Framework for Aquatic Biogeochemistry (Bruggeman & Bolding, 2014)
[4] General Ocean Turbulence Model (Burchard et al., 1999; Umlauf & Burchard, 2005)
[5] General Estuarine Transport Model (Burchard & Bolding, 2002; Klingbeil & Burchard, 2013)

have been implemented as a generic modular component and tested using observational data (Nasermoaddeli et al. 2014a,b). For the stations NOAH-C and Helgoland Roads, a high sensitivity of SPM concentration and its transport on ecological processes has been found. In shallow waters (<25m) the fundamental importance of wave effects became evident.

All partners created the software MOSSCO, which currently comprises 80000 lines of code (Lemmen et al. 2013, Hofmeister et al. 2014, Nasermoaddeli et al. 2014a,b, Lemmen & Hofmeister 2015). In the underlying concept, two levels of modularity are distinguished: (1) the level of Earth System domains (e.g., benthos, pelagic), (2) and the process level (e.g., algal growth, particle flocculation). A hybrid coupling strategy ensures and optimises communication both *between* compartment models and *within* single compartments. Information exchange between domains using different grids requires a software library like ESMF (www.earthsystemmodelling.org) that provides a coherent numerical integration frame for running a system comprising diverse components. Components can be data bases (e.g. observation data of KüNO partners), or 3D coupled models and model systems. ESMF components have been developed within MOSSCO phase I for: the 3D ocean models GETM and HAMSOM, generic input/output facilities, the Delft3D erosion/sedimentation module, and spatial representations of the FABM framework for both water column and soil processes.

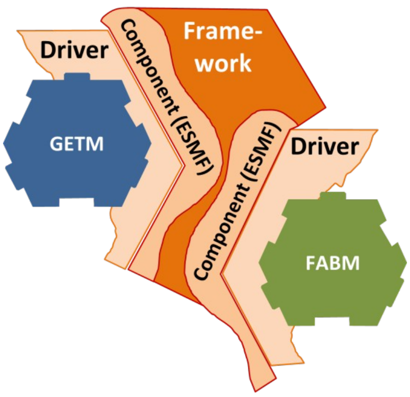

Fig. 1: Two-layer coupling concept developed within MOSSCO, acting as “glue” between models and coupling frameworks.

Modularity within Earth System compartment models can be achieved by FABM, which supports an efficient handling of state variables within different modules. Available process modules brought into the FABM structure describe ecosystems (NPZD, MAECS, ERGOM), microphytobenthos, passive tracers, SPM, amongst others.

The feasibility of the MOSSCO approach has been demonstrated by assembling existing modules and refining available setups. As a setup, we regard the complete set consisting of a modularly coupled application together with boundary conditions (e.g. topography), forcing (e.g. atmospheric wind), and parameter sets. For example, high-resolution simulations (50 m) have been performed for the Wadden Sea near Amrum to provide flooding times and bottom shear stresses to the partner project STopP (Schwemmer et al. submitted). All setups and source codes have been released to the public, and are available from the http://sf.net/p/mossco developer site. For NOAH, a benthic-pelagic biogeochemistry setup has been tested for their station C in the SNS and NOAH staff has been trained on using this MOSSCO setup.

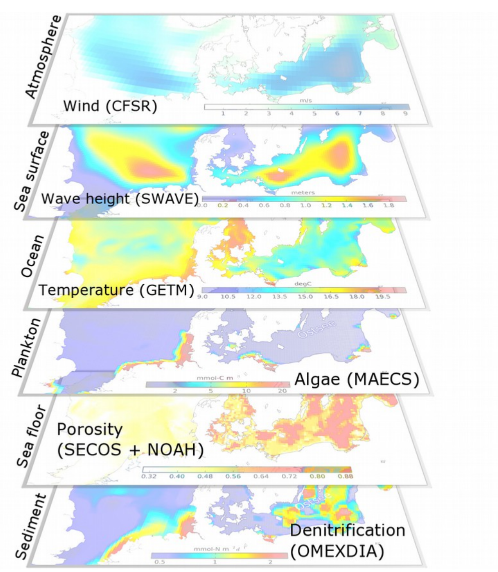

Fig. 2: Modular 3D system dynamics for NSBS, extending from the atmosphere into the sediment.

For investigating the North Sea--Baltic Sea (NSBS) system synoptically, a setup was created covering both seas with a grid resolution of 6 nm. The coarseness of this setup allows the easy web-based distribution to end users. Even at this low resolution, stratification and coastal fronts are well represented in a simulation for the year 2009, compared to MyOcean and COSYNA observations. The unified approach to modelling both seas in MOSSCO (Fig. 2) had underlined the relevance of basin scale physics for explaining different biogeographical regimes. A modularly coupled application of hydrodynamics, pelagic ecosystem and SPM, and erosion-deposition also enabled investigations of biologically altered sediment dynamics; a new dataset on critical shear stress has been compiled by Kösters & Winter (2014) and recently extended to include the effect of *Tellina fabula* distribution in the German Bight.

A new and generic input module has been developed to introduce forcing data or model output into the coupled system. With this new component, we have, for example, been able to synthesize the porosity maps delivered by the NOAH (North Sea) and SECOS (Baltic Sea) sister projects, which include still ongoing harmonisation of methodologies guided by MOSSCO. The spatial distribution of porosity is an important factor for the calculation of benthic-pelagic fluxes, and thus nutrient retention capacity of the sediment. Using the new input component we also integrated new data on river basin flows of water (discharge) and nutrients (P, N, Si) that have been compiled from the MONERIS discharge model and from observations stations along the North Sea operated by government agencies. Currently, even the smallest German rivers are being added to this comprehensive data set. The modular inclusion of riverine nutrient discharges results in a spatio-temporal distribution of simulated Chl-a that is consistent with observational data and of N:P stoichiometry that is relevant for evaluating nutrient target values in the SNS (Kerimoglu in prep.).

First results from the NSBS joint setup have been made available to the public via the WebGIS (www.mossco.de/webgis), where simulation results can be directly compared with COSYNA observations. Until the end of the MOSSCO phase 1, ensemble predictions for variability analysis and scenarios (e.g. eutrophication) will be added to this portal. Beyond the project partners, MOSSCO is already used by two research groups at the University of Hamburg, where hydrodynamic, ecological and tracer models are adapted to the modular coupling system. Furthermore, within the recently started project LOCUS, IOW in cooperation with TROPOS use MOSSCO to couple the ocean model GETM with the atmospheric model ICON.

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BIg) Work plan

The work flow is organized through five work packages (WP), each of which contains 4-11 tasks. In three applied WP (WP3-5), research and management questions relevant to the call are addressed. These applications depend on infrastructure (WP1) and the configurations tailored in WP2. Because of the interdisciplinary expertise required when working with coupled models, two or three project partners contribute to each WP. Joint tasks not included in WP descriptions are (1) the distribution of products to stakeholders and coastal mModellers, (2) contributions to summer schools, workshops, and conferences and (3) continuous feedback on documentation and functionality to WP1.

WP1 Modular infrastructure (lead by HZG)

Workload *20 FTE: HZG 6 (+6 affiliated), IOW 4(+4);* ***Dependency****: functionality of external software packages;* ***Product****: Daily available functional software;* ***Deliverables****: (D1.1) Active user group at project partner institutions (and beyound); (D1.3) User guide;* ***Milestone****: (M1.1) Regridding facility (month 15)*

This WP will provide (a) a functional software package, (b) support in using the MOSSCO software, (c) adaptations to changing computing infrastructure, and eventually (d) solutions to new user demands. New users of the software within and beyond the project institutions will be engaged.

MOSSCO operates on a wide range of computer systems, including personal laptops and massive parallel computers, Linux, Mac and Unix operating systems. These environments change over time, such that software needs to be constantly adapted and tested (T1.1). With increased usage, errors in the software ("bugs") become apparent; new questions are asked by users that should be answered in documentation (T1.2). The infrastructure for user support, error reporting, open-source code development, and documentation needs persistent maintenance. The projection between different spatial representations of data (regridding) is a central task of a modular system, which allows operation on different spatial representations as needed, e.g., in WP3-5 (T1.3). ESMF already provides infrastructure for regridding, but additional work is needed to implement this feature for existing and forthcoming components, to provide consistent configuration for regridding, and to ensure mass conservation during interpolation. Dissemination activities include scientific papers on the coupling approach and organization of regional and international workshops (T1.4)

The existing documentation is to be updated according to user feed-backs, addressing three different user groups: (a) scientists with citable publications of the research behind MOSSCO, (b) developers who want to contribute to MOSSCO, and (c) users of specific components or integrated applications. Tasks within this WP are (T1.1.) Code maintenance and testing; (T1.2) technical documentation and user support, leading to increased user base at partners (D1.1); (T1.3) implementation of a “regridding” capability (milestone M1.1); (T1.4) scientific publication.

WP2 Model configuration (lead by IOW)

Workload *40 FTE IOW 12(+6), BAW 7(+7), HZG 6(+2);* ***Dependency****: maintained MOSSCO (WP1 T1.1); zebra mussel parameterisation (SECOS); CMAQ, EMEP, HAMSOM, UnTRIM-Sedimorph data.* ***Deliverables****: (D2.1) High-resolution setups (D2.2) Simulation results for reference decade, past/future scenario in WebGIS;* ***Milestones****: (M2.1) SNS and WBS near coast setup (month 12), (M2.2) suspension feeding model (month 14), (M2.3) Western Oder Lagoon and NSFS setup (month 19), (M2.4) scenario data (month 26), (M2.5) SPM aggregation model (month 7), (M2.6) dynamic macrofauna model (month 14).*

The goal of this WP is extension of processes descriptions (particle coagulation, macrofauna) and spatial refinement, both required for the applications within WP3-5. The reference decadal simulation aims at guiding MSFD parameters, and for comparison with future and historic scenarios.

Tasks within this WP are (T2.1) Build/adopt 600 m SNS/WBS setups; (T2.2) Implement flocculation model; (T2.3) Extend existing geomorphology model by bed load transport model; (T2.4) Adopt and develop filtration and macrofauna models; (T2.5) Compile hydrographic and BGC data for 2002-2013; (T2.6) Create scenarios for 1880 and 2080; (T2.7) Create 150 m resolution NSFS setup; (T2.8) Create 100 m resolution setup for Western Oder Lagoon.

Previous projects (e.g. AufMod, PACE) and predecessor studies in phase I have shown that the dynamics of SPM is insufficiently described by the physical and pelagic processes alone. Settling velocity of cohesive particles are largely determined by aggregation and resulting floc properties. Coagulation efficiency (particle stickiness) again depends on plankton exudation. We thus plan to adopt a simplified version of the aggregation model of März and Wirtz (2009) dependent on exudates and shear rates calculated by the ecosystem model and the turbulence model (MAECS, GOTM within GETM). Filtration of SPM by benthic macrofauna changes lateral transport patterns and transforms the size distribution and quality of particulate matter at the soil interface. Bed load transport, known to contribute to residual particulate transport in coastal areas (cf. AufMod), is integrated into the MOSSCO suite through the SediMorph model.

The macrobenthic module will be built in stages (T2.4): (1) based on SECOS and BaltCoast results a parameterisation for zebra mussels will be formulated, including clearance, ingestion and egestion activity. (2) For prescribed mussel densities the induced transformation of SPM (change of size spectrum) and local sediment structure is parametrized, making use of available models (e.g., Kitazawa et al. 2008). (3) A trait-based macrofauna model, based on linkages between traits and functions (e.g., feeding type, feeding depth, clearance, bioturbation) is devised within an already initiated collaboration with J. Holstein/D. Fiorentino (AWI), and T. Neumann/H. Radtke (IOW, SECOS). (4) Jointly with AWI and SECOS (M. Gogina) spatial maps of bioturbation/bioirrigation will be integrated into the MOSSCO-system. (5) Spatio-temporal variations are resolved by the trait-based model using an optimality approach like Wirtz (2013).

Validation data (mainly SST, Chl-a, SPM) will originate from COSYNA (MERIS, FerryBox), IOW/HELCOM, MDI-DE, and for benthic BGC states from observations by NOAH and SECOS. All four setups will be based on the BSH high-resolution topography. Boundary conditions for SNS/WBS will derive from the NSBS 6nm setup (see section BIf, Fig. 2), or an existing NSBS 1nm setup. Forcing and boundary data for the reference decade 2002-2013 as well as hydrodynamic and sediment dynamics for the NFNS simulated by an associated coastal engineering KüNO-proposal will be integrated via the regridding facility (T1.3), also including N and P deposition from EMEP and CMAQ, climate/weather forcing from CSFR and CLM/CoastDat. From these models, boundary conditions for a historic (year 1880) and future (year 2080) scenario will be derived.

Applied work packages WP3-WP5

A system understanding of coastal particle and BGC dynamics and of usage intensification effects on the coast will be demonstrated by WP3-WP5. These three application WPs demonstrate and utilise the added value of the modular approach developed in MOSSCO. Each WP addresses scientific questions to specific coastal regions that are also relevant for coastal management and the formulation of regulatory goals in the MSFD or a re-assessment of procedures in the WFD. The questions are aligned at a cycle of relevant process interactions thus enabling studies on feed-backs between major ecosystem compartments:

POC settling and soil granularity → macrofauna composition	WP5
Macrofauna composition/activity → remineralisation and sediment stability	WP3, WP5
Suspension feeding → primary production and nutrient levels	WP3, WP4
Primary production → SPM/POC settling and resuspension	WP3, WP5
Residual circulation → lateral SPM/POC accumulation	WP3

WP3 Near-coast material cycles (lead by HZG)

Workload *50 FTE, HZG 11 (+18), IOW 9, BAW 6 (+6);* ***Dependency****: regridding (WP1 T1); model setups (WP2 T1.5-6, 8-9); SECOS/NOAH macrobenthos data, NOAH denitrification data, SECOS/BACOSA simulation results for changes of ecosystem service.* ***Deliverables****: (D3.1) SNS & WBS simulations 1880, present & future (month 24).* ***Milestones****: (M3.1) SNS near coast simulation (month 24), (M3.2) process test particle trap (month 28), (M3.3) Secchi depth validation WBS (month 30).*

The first goal of this WP is the creation of near-coast high resolution reference states and budgets for BGC and particle dynamics (C, N, P, and SPM). Based on these reference simulations, WP3 seeks to quantify the role of interfaces and feedback processes and to address management problems related to coastal water quality. The high spatial resolution enables analysis on the determinants of coastal N- and P-gradients. This central WP will conduct sensitivity tests at the level of single process parameters (calibration), process areas (modular exchange), forcing (scenario analysis), and of process descriptions (model intercomparison).

Tasks: (T3.1) Data-model comparison hydrodynamics (with SECOS); (T3.2) comparison for BGC and SPM in SNS; (T3.3) Comparison benthic denitrification (NOAH); (T3.4) Integration of macrobenthos; (T3.5) SPM budgeting and its sensitivity; (T3.6) Identify coastal BGC provinces; (T3.7) Evaluation of water quality indicators; (T3.8) decadal, past and future simulation; (T3.9) Model intercomparison; (T3.10) Integration in WebGIS and joint publications.

Nearly the complete set of modules will be employed, encompassing benthic models (BGC: OMEXDIA, sediments: EROSED, macrobenthos: first empirical models from NOAH, SECOS, AWI, later model developed in WP2), pelagic ecosystem and SPM models, physical drivers and atmospheric forcing prepared in MOSSCO-I and WP2. The skill of single model components and of the coupled system will be assessed using data compiled in WP2. Physical validation will focus on stratification reconstructed from Scanfish and ADCP data for SNS, and SST and salinity for WBS (T3.1). Calibration of BGC and SPM models will focus on critical parameters (e.g., settling velocity, attenuation, T3.2-4). WP3 will evaluate process rates behind the reference dynamics and conduct modular sensitivity tests, in which process areas (esp. SPM transport/settling/erosion) are replaced by alternative descriptions such as constant fields (T3.5). Referring to the above introduced process cycle, this analysis will be organized along major process and compartment interfaces:

benthic-pelagic	ecology-BGC	bioturbation → remineralisation and denitrification
benthic-pelagic	ecology- geology	suspension feeding → phytoplankton production & SPM transport
coast/shelf	physics- geology	density-driven circulation → SPM transport
coast/shelf	BGC-geology	exudation → particle aggregation → settling velocities
coast/shelf	geology-BGC	SPM gradients → primary & secondary production → nutrient levels

The linkages in the listed control relations guide the analysis of potential feed-backs. Determinants of SPM transport along and across the coasts in SNS will be investigated in more detail at higher spatial resolution in WP5. BGC in WBS will be jointly done analyzed with SECOS. This synthesis work (T3.6), with focus on benthic remineralisation, may lead to a generalisation of findings to different types of coastal ecosystems.

Based on the improved state estimates of, e.g., water turbidity, chl-a, and nutrient concentration, the project will support authorities (UBA, LUNG, LLUR) in their management and reporting for the EU WFD and MSFD. This support includes (a) re-assessment of water type regionalisation (T3.6), (b) scenario runs, (c) a proxy-indicator evaluation, and (d) a model uncertainty analysis.

Scenario simulations (T3.8) will comprise a “pristine” background scenario corresponding to a Good Environmental Status (GES) from WFD/MSFD, e.g. for 1880 like proposed by Schernewski et al. (2015) and a future scenario (2080) with national and international load reductions (e.g. Baltic Sea Action Plan, OSPAR) and severe Climate Change scenario (e.g. RCP 8.5). The pristine scenario will make use of the extensive work on river loads in the North Sea and Baltic Sea area (LINK to web-site). Existing results and target values (e.g., Schernewski et al. 2015) will be adjusted for the WBS (insofar not covered by SECOS-I) and enlarged with respect to Secchi Depth targets. Also using new satellite data (Stock et al. 2015), we will investigate whether Secchi depth can be used as spatially-explicit eutrophication proxy (T3.7) and if it can be harmonized with other biological WFD-targets and the historical distribution of submerged macrophytes. A revision of existing targets for coastal North Sea waters will be discussed and results for the SNS shelf area compared to existing projections made for OSPAR. Simulations results (present, historical state as indicator for the GES and future) are provided to SECOS and BACOSA for their work on ecosystem services.

On demand of relevant authorities, we plan to exploit the modular capability of MOSSCO in order to perform an ecosystem model intercomparison (e.g. ERGOM, MAECS, ECOSMO, ECOHAM). This will for the first time allow for a quantification of existing inter-model uncertainty (T3.9) and may lead to strategies for reducing the large divergence between model outcomes, which has led to reservation of policy makers responsible for WFD and OSPAR. In the interaction with authorities, specifically tailored reports will be produced that summarize relevant findings. A major publication activity will result from the analysis conducted at different levels throughout WP3 (T3.10).

WP4 Mussel farm establishment Oder Lagoon and generalisation (lead by IOW)

Workload *20 FTE, IOW 11 (+2), HZG 6 (+1),* ***Dependency****: model setups (T2.8); filtration model (T2.4); near-coast boundary conditions (WP3); regridding function (T1.3);* ***Deliverables****: (D4.1) Quantification of water quality improvement and side effects for Oder Lagoon (month 30); (D 4.2) Publication on water quality effects (month 36);* ***Milestones****: (M4.1) generalized mussel farm module, interplay water transparency (month 34); (M4.2) optimized farm structure (month 30); (M4.3) WBS/NFNS applications (month 36)*

For sustainable corrective actions in the coastal zone, the use of naturally occurring fauna and flora has been suggested (Schernewski et al. 2012). This concept, termed “building with nature”, is currently investigated in pilot projects such as Ecoshape, SubMariner, Baltic EcoMussel; or in the Waterschap Brabantse Delta. Within the BONUS-project BaltCoast, a set of measures for improving local water transparency (mussel farming, artificial reed belts, and groin systems) will be explored in the Oder Lagoon. Given the broadness of measures, funded modelling activities in BaltCoast have to leave relevant aspects unresolved so that we here seek to exploit the MOSSCO system focussing on mussel farms to generate simulations at sufficient resolution and reliability (using plausibility tests), and covering all major ecological and socio-economic consequences, including possible side-effects such as anoxia or reduction in SPM levels. The strong synergy between MOSSCO and BaltCoast will in particular enable a generalisation of the approach to other areas (with WP5). For example, mussel aquaculture was also proposed for offshore wind farms (Buck 2007).

Using the regridding function (WP1), different shapes of mussel farms and their interplay with the current fields can be resolved and analysed for optimizing the horizontal architecture of the measures in terms of water transparency improvement. WP4 will study impacts of faeces and pseudofaeces on bottom oxygen concentration using the benthic BGC module (WP3). WP4 participates in the ecosystem model intercomparison (WP3) to assess the uncertainty of recommendations.

Tasks: (T4.1) Adoption of Oder Lagoon setup, model configuration from BaltCoast and T2.8, high resolution simulation with physics, ecology, BGC, early diagenesis and particle dynamics; (T4.2) Analyse farm's possible effects on water quality, model-comparison together with WP3; (T4.3) Use sub-grids to optimize horizontal farm layout; (T4.4) Parameterisation/generalisation of the filter feeder module; transfer to mussel farming to other coastal waters in WBS and at windparks in the NF or SNS area (with T5.6); (T4.5) Publication on mussel module, effects on water quality.

WP5 Macrobenthos in the North Frisian transitional zone (lead by BAW)

Workload *20 FTE, BAW 5 (+5) HZG 4 (+6);* ***Dependency****: model setups (T2.8); filtration model (T2.4); near-coast boundary conditions (WP3);* ***Deliverables****: (D5.1) Quantified system effects of macrobenthic interaction;* ***Milestones****: (M5.1) Validated model-generated macrobenthic distribution; (M5.2) Disturbance simulations of benthic dynamics (month 33)*

The goal of this WP is to develop a mechanistic, trait-based description of the macrobenthic community for studying the interplay of macrobenthic and ecosystem dynamics. WP5 relates simulated macrobenthic trait and biomass variations to observational data and performs (conceptual) studies on how these variations affect relevant ecosystem services and SPM budgets.

The work plan contains five tasks: (T5.1) implements and run a 150 m resolution fully coupled simulation for the NSFS; simulations are nested into the SNS setup (T2.1) and will cover the years 2000-2005 and 2010-2013 to match observational data. (T5.2) Validate physical, ecological, and BGC simulation with station data (FINO3, NOAH-E, Helgoland, Sylt) and FerryBox. (T5.3) Create disturbance scenario for building activity and run sensitivity simulations; (T5.4) Evaluate disturbance scenarios for ecological, water quality, and ecosystem services impacts; transform macrobenthos empirical models from NOAH and SECOS to trait parameter (e.g. feeding mode, vertical niche) and validate model; T(5.5) Create flooding and salinity statistics for STopP and atlas.

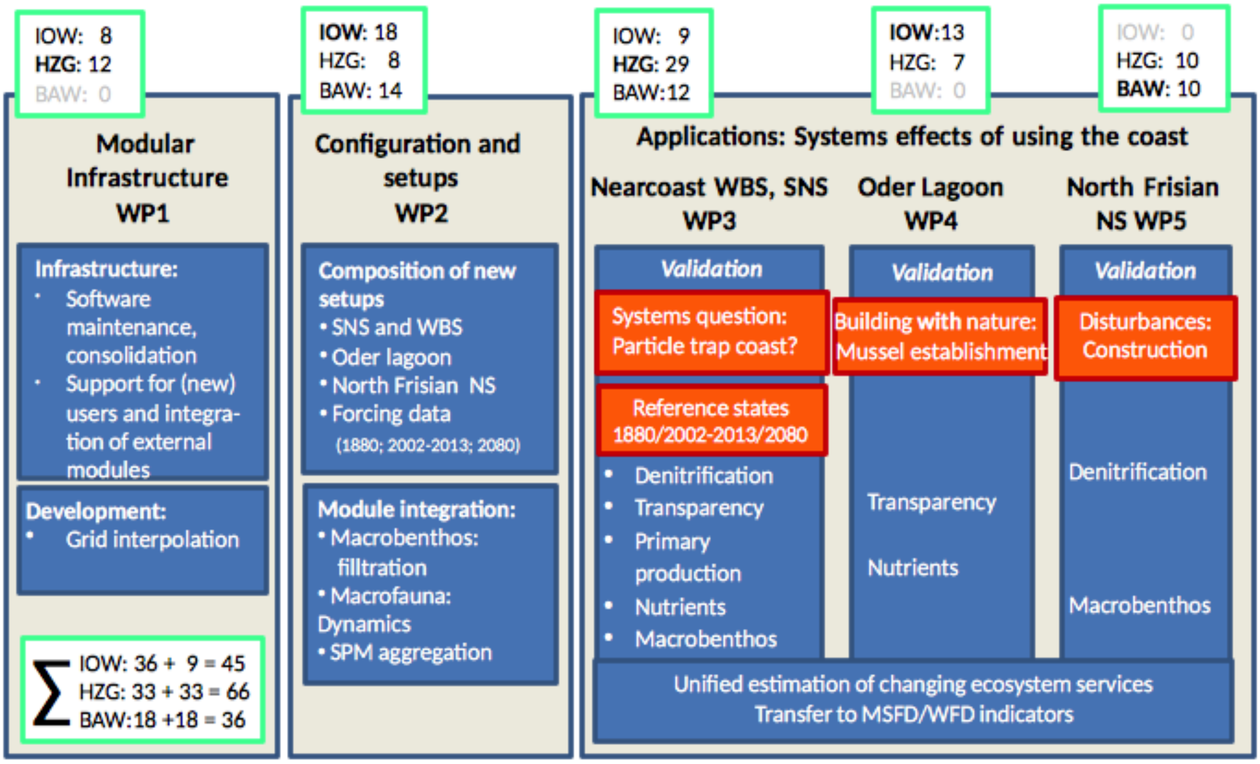
The implementation of the setup includes joint work with C. Winter (NOAH) on bottom morphology. Throughout this WP, the model configuration includes as macrobenthic module with increasingly elaborated versions of the trait-based model from T2.4. This module will be intensely compared to ship observations in 2000-2005 (D. Fiorentino, AWI Sylt). The validation work is expected to lead to a reference parameter set and uncertainty estimates. These products allow for conducting and interpreting sensitivity studies, both from a scientific as well as a management perspective (T5.5). The conceptual sensitivity studies will explore the role of slowly changing seasonal drivers (e.g., POC input) and of short-term (but recurrent) disturbances such as physical events (e.g. storms) and anthropogenic activities. The latter disturbances may result from offshore constructions (e.g., pipelines/cables or piles), ground net fishing, or sediment discharge and mining, which will be described through idealized scenarios. Results will also be discussed with other sister projects (NOAH, STopP). This conceptual work will in particular be continued to unravel possible feed-backs of macrobenthic dynamics on water quality and transparency and ecosystem functioning (e.g. denitrification rate and primary production) of the North Frisian transitional waters ecosystem. In a specific application, water quality changes due to additional mussel growth at offshore windfarm piles will be assessed using the module developed in WP4 (T4.6, T5.4).

It is intended to use this near-coast set-up and further investigate its results within an associated coastal engineering project proposed within the FONA³ framework.

BIh) Project management

Work division and work package scheduling

The work division between the partners will be kept similarly to the prior funding phase. Based on the successful experience of a day-to-day close working relationship between the partners, many tasks do not occupy 100% of a person's work load at one institution, but are split between the partners.



HZG and IOW lead the infrastructure (WP1, Wirtz) and configuration (WP2, Burchard) work packages, and each of the partners leads one of the application work packages WP3 (Wirtz, HZG), WP4 (Schernewski, IOW), and WP5 (Kösters, BAW). The project will be supported by the secretariat at the coordinating institution HZG.

Communication

Weekly online meetings have been established to ensure the knowledge transfer between all project participants; quarterly face-to-face meetings are scheduled. All common resources are operationally available 24/7 to all partners (and the public) on an sf.net hosted internet platform that serves a project wiki, a tech blog, a bug tracker (www.mossco.de/bugs), the complete MOSSCO documentation (www.mossco.de/doc), and the version-controlled source code (www.mossco.de/code). Controlling and quality assurance measures have been implemented already in phase 1. All doctoral students associated with MOSSCO will be guided by an external

PhD panel that audits the supervision and progress of each PhD project. MOSSCO personnel contributes to the annual PhD coastal summer school organized by HZG. The coordinator supports the KüNO scientific steering committee.

	Project month		1	2	3	4	5	6	7	8	9	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3
	Year		2016									2017												2018												2019		
	Calendar month	Load	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
WP1	1.1 Maintenance	17%	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	1.2 User Support	14%	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
	1.3 Regridding	100%	0	0	0	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1.4 Publication	40%	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0	0	0	0	0	0	0	0	0	0	0
WP2	2.1 SNS/WBS setups	40%	t	t	t	t	t	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	2.2 Flocculation model	100%	f	f	f	f	f	f	f	f	t	t	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	2.3 Geomorphology	100%	t	t	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	2.4 Filtration models	50%	t	t	t	t	t	t	t	t	t	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	2.5 Decadal data	100%	f	f	f	f	f	f	f	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	2.6 Scenario data	50%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	2.7 NSFS setup	100%	f	f	f	f	f	f	f	f	f	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	2.8 Oderhaff setup	100%	f	f	f	f	f	f	f	f	f	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
WP3	3.1 Hydrodynamics valid.	100%	f	f	f	f	f	f	f	f	f	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	3.2 Comparison BGC	50%	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	t	t	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	3.3 Denitrification valid.	50%	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	3.4 Makrobenthos	75%	t	t	t	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	3.5 SPM budget	50%	f	f	f	f	f	f	f	f	t	t	t	t	t	t	t	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	3.6 BGC zonation	100%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	f	f	f	f	f	f	f
	3.7 Water quality indicat.	50%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	t	f	f
	3.8 Scenario simulation	50%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	t	t	t	f	f	f	f	f	f
	3.9 Model intercomparison	50%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	t	t	t	t	t	t	t	f	f
	4 KüNO integration	50%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	t	t	t	t	t
WP4	4.1 Oder Lagoon simul.	100%	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	4.2 Consequences BGC	100%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f
	4.3 Optimization far	100%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	f	f	f	f	f	f	f	f	f
	4.4 Mussel generalisation	50%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	t	t	t	t	t
	4.5 Publication	20%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	t	t	t	t	t
WP5	5.1 NFNS simulation	100%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f
	5.2 NFNS validation	100%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	f	f	f	f	f	f	f	f	f	f
	5.3 Disturbance scenarios	100%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	f	f	f	f	f
	5.4 Ecosystem Services	100%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t
	5.5 Flood, salinity stats	40%	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	t	t	t	t	t	f	f	f	f	f	f	f	f	f	f	f	f

Personnel funding and own contribution

Despite increased personnel costs, the requested funding amount has been reduced to 80% of the amount funded in phase I. Overall, we ask funding for 87 full time employee (FTE) months, less than one position per partner. The proposed work load is 147 FTE, such that each of the partners significantly contributes institutional staff to the project. BAW matches the 18 months requested (50%), HZG matches the 33 months (50%), and IOW complements the 36 months request by another 9 months (25%). Overall, the work-plan relevant contribution of the institutes is 60 FTE. In addition, the partners each contribute work time for coordination, secretarial and computing infrastructure: 12.5% Burchard, 12.5% Gräwe (IOW), 10% Kösters (BAW), 10% Kapitza, 20% Wirtz (HZG), and 15% secretarial support Hartmann (HZG). At each partner institute, PhD students are associated with the project (HZG: C. Zhao; BAW: I. Holzwarth, forthcoming KüNO Engineering PhD; IOW: LOCUS PhD S. Müller).

Consumables and compute resources

The partner institutions will cover all consumables from their own budgets; they have access to and contribute several supercomputers (HLRN, DKRZ, BAW, HZG-Cluster) for massively parallel computations in high spatial resolution. A proposal for computing time at Jülich Supercomputing Centre has been submitted.

Cooperation

MOSSCO closely cooperates with running KÜNO sister projects, with planned associated projects in the engineering FONA³ call, with the coastal ecology work package of PACES (Helmholtz research program), LOCUS (atmosphere-ocean coupling cooperation of IOW and TROPOS Leipzig), AEMON aquatic ecosystem modelling network, and with the BaltCoast project at IOW.

Risk management

We identify the following risks for the project and propose mitigation strategies:

Risk and impact	**Mitigation strategy**
Failure or downtime of external hosting platform sf.net or internet;	Distributed source code management with complete local mirroring and source code history.
Failure of HPC infrastructure: impacts or delays high-resolution 3D simulations.	Diversification to various HPC platforms in Jülich, Warnemünde, Hamburg, Berlin, and Geesthacht
Large changes in external models or software: requires unexpected increased maintenance	Direct Involvement in GETM/FABM development; sub-contracting; substitution of third-party modules
Personnel fluctuation. Parental and sick leave time or change of employer endanger tasks.	Integration of external developers (subcontracting) to spread expertise. Tenure-track options (planned for HZG)

BIi) Dissemination and data management

Patents and licenses

The software developed within MOSSCO is copyrighted by HZG and partners and released to the public under the open source GNU license v3, thus being free of charge, modifiable and available as source code. All documentation is released under the Creative-commons Share-Alike Attribution license, i.e. free of charge, open, and modifiable, with the implication of releasing derived works under the same license and with proper attribution to MOSSCO.

Open Access and Data Management

The MOSSCO software and its documentation are developed as open source (see above). MOSSCO publications in scientific journals honor the Berlin Declaration on Open Access. MOSSCO strictly follows the DFG's memorandum on Safeguarding Good Scientific Practice. Project products are redundantly stored on http://sf.net and every participants work computers; Simulation results are generally too large to be stored completely; thus every simulation is enriched with metadata describing all details necessary to reproduce the results; reduced simulation results are then uploaded to the WebGIS operated by KüNO and COSYNA.

Economic prospects

No immediate economic gains are projected for the project partners. The chosen license model, however, allows anyone to use the software and to create added value. However, MOSSCO creates a business opportunity of consulting governmental agencies, research labs and the industrial sector.

Scientific prospects

The FONA call "Küstenmeerforschung in Nord- und Ostsee" formulated the necessity of devising a modular coastal model system, that facilitates the collaboration between German coastal research institutes and agencies. With the applications performed in this funding phase, the utility and relevance of the coupled system is demonstrated, and deployment at different labs will be consolidated. The MOSSCO infrastructure, and the expertise created on coupling coastal processes will strengthen the scientific profile of the partners: it will make them more attractive partners in national and international scientific cooperations such as TROPOS. MOSSCO strengthens the Ecosystems Approach to Management by providing a quantitative understanding of eutrophication, sediment transport and benthic-pelagic coupling, which is key to the implementation of the WFD, the MSFD, and BSAP.