KONINKLIJKE NEDERLANDSE
AKADEMIE VAN WETENSCHAPPEN

I. 6 / ORSTEL ALGEMEEN

Acroniem	MORP
Naam van de infrastructuur	Multifunctional Ocean Research Platform
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KONINKLIJKE NEDERLANDSE
AKADEMIE VAN WETENSCHAPPEN

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Samenvatting
Geeft korte samenvatting van deze faciliteit in termen van werking, wetenschappelijke voordelen etc. (max 350 woorden).

Next to major challenges in both the vast outer space and the physics of extremely small subatomic particles, it is our own ocean that is the final frontier man will be crossing in the 21st century. Growing demands for mineral and organic resources will inevitably lead to exploration of the seas and oceans, including the deep sea. However, ongoing exploitation, pollution, overfishing and cumulative effects of climate change are impacting biological functioning of the oceans and changing ocean dynamics and chemistry. There was, is, and will remain an urgent need to investigate the oceans and especially the deep sea as large ocean territories are currently under threat and might be seriously affected before they have even been investigated. These areas are, however, also notoriously difficult to access, which calls for a highly specialized and dedicated approach geared towards open-, and deep-sea operations devoted to fundamental research. The success of such efforts depends on our ability to access these remote areas and hence a dedicated multi-disciplinary ocean going research platform, with essential equipment is crucial for this much needed research.

Dutch marine research is presently still at the international forefront in terms of publications and technical innovations. We now need to invest in order to maintain our traditional international stronghold of Dutch marine industries and knowledge as well as informed marine policy making. The research vessel *R.V. Pelagia*, the current single national ocean-going research platform, is now 25 years old and will need to be replaced within the coming five years. Keeping the current vessel operational longer would result in unsustainable increases in operational costs. Without a national research platform we will lose our position at the forefront of priceless knowledge of the global oceans and processes therein. Therefore, we here seek funding for a novel ocean-going research vessel embedded in a Dutch National Marine Facility (NMF), setting the stage for the next generation of marine researchers. Such a facility will maintain existing and develop new facilities for marine research in the widest possible sense for the benefit of the integrated Dutch Marine academia, applied research institutions, policy makers and industry.

Kernwoorden
Geef maximaal 8 kernwoorden die de faciliteit typeren.
ocean research platform, marine technology, fundamental marine sciences

II. VOORSTEL INHOUDELIJKE UITWERKING

A. SCIENCE AND TECHNICAL CASE

Volledig nieuwe faciliteit of verbetering van reeds bestaande

- Beschrijf in hoeverre het hier een geheel nieuw idee betreft of een verbetering of opvolging van een reeds bestaande faciliteit.

The Dutch marine research community is currently using the ocean going research vessel *R.V. Pelagia*, including a vast array of associated research equipment. This vessel, which also forms the Dutch contribution to OFEG and thus guarantees national access to the European pool of marine vessels, has been functioning as the main ocean research platform for the Netherlands for the past 25 years. Because of various operational and exploitation reasons, including changing naval legislation, safety regulations and the like, this vessel will need to be replaced within the coming 5 years as keeping the current vessel operational longer would result in unsustainable increases in operational costs. Moreover, due to rapid technological developments a new vessel is also needed to provide a platform for novel systems, that will allow for innovative chemical, biological and physical research. Organizational, the former 'Marine Research Facility (MRF)' embedded within Royal NIOZ, and supported by NWO has functioned over the years as hub for marine research, providing the technical and logistical support for all marine research within the Netherlands. With the restructuring of NWO and Royal NIOZ, MRF has now evolved in a separated business unit of Royal NIOZ, the National Marine Facility, NMF, as a new department.

New marine technological developments are redirecting the focus of observations towards un-manned vehicles such as gliders, Autonomous Underwater Vehicles (AUVs) and crawlers. Existing techniques and the further development of these techniques require intensive cooperation between technological and scientific departments within a hardware environment. Although such systems are autonomous, this equipment still requires a ship for transport to the deployment location and also for regular maintenance. This requires developing a next generation research vessel/platform for the Netherlands, as a concerted effort by Dutch academia, research institutes and industry. In the international Marine research and technology theater such a ship will not only provide the platform needed for successful science, but also act as a showcase for international trade.

The new to develop research vessel should satisfy several boundary conditions:

- In view of the limited financial resources of the Dutch scientific community the research vessel should not exceed 70 meter, allowing it to be operated with the current number of crew.
- The number of berths for scientists should be increased from the current number to about 22, allowing larger projects and/or cruises, in which projects can be combined. This makes it easier for individual scientists as well as consortia to seek funding for ocean going activities as multiple projects share costs.
- The vessel should be of Ocean class, allowing the ship to be operated in <u>all</u> Dutch territorial waters as well as in key areas to monitor early indicators of changes in the ocean-climate system.
- Deliberately targeting a niche within the international field of research vessels we aim at developing an all-weather ship, allowing research under stormy conditions, essential for a.o. understanding large scale ocean circulation, gas-exchange with the atmosphere and mixing of the water column. Similarly, a limited Ice class will add to the versatility of the vessel under these conditions. Stand-alone observational devices should be launched, operate and recovered under the widest possible conditions from the vessel.
- The vessel should provide a stable platform for new state-of-the-art both technical and biological techniques.

Science Case
- Geef een algemene introductie van de wetenschappelijke waarde van de faciliteit. - Beschrijf de wetenschappelijke voordelen en verwachte doorbraken. - Beschrijf hoe deze faciliteit zich verhoudt tot alternatieve faciliteiten/onderzoeksmethoden.

Introduction

As stated above, next to major challenges in e.g., outer space and sub-atomic physics, the unknown ocean is the final frontier man will be crossing the 21st century. The ever growing demand for resources, mineral and organic, food, energy, transport, etc. will inevitably lead to expansion into the seas and oceans, including the deep sea. However ongoing exploitation, pollution, overfishing and cumulative effects of climate change are impacting biological functioning of the oceans and are changing ocean dynamics and chemistry. There was, is, and will remain an urgent need to investigate the still largely unknown oceans and especially the deep sea as large ocean territories are currently under threat and might be lost before they have even remotely been investigated. These areas are, however, also notoriously difficult to access, which calls for a highly specialized and dedicated approach geared towards open-, and deep-sea operations dedicated to fundamental research. The success of such efforts depends on our ability to access these remote areas and hence a dedicated multi-disciplinary ocean going research platform, with essential equipment is crucial for this much needed research.

Below, we elaborate the major marine scientific themes, pertinent to Dutch marine sciences in the various disciplinary fields. This concerns a multi-disciplinary perspective to which a large array of colleagues in the field contributed, listed below.

Theme 1: Ocean geochemistry and biogeochemical cycling

OCEANS AND CLIMATE

The world Oceans represent 71% of the surface of our planet, and the volume of seawater of the ~4 km deep oceans is enormous. The oceans have a major control on the daily weather, the long-term climate and climate change, and the composition of the atmosphere. Every year mankind emits ~37 Petagram CO_2 into the atmosphere, of which ~30% is taken up by the oceans (1 Petagram CO_2 = 10^{15} gram CO_2; compare biomass of all mankind, ~7 billion people, is merely ~0.4 Petagram). Thus without the oceans the rapid increase of CO_2 in the atmosphere would be even ~30% faster. The extra CO_2 greenhouse gas in the atmosphere causes global warming. Almost all of the extra heat enters the oceans, some 93%. Another ~3% is causing the melting of ice. Arctic sea-ice is rapidly disappearing, glaciers on land are diminishing, and the ice-sheets of Greenland and West Antarctica also decrease, one of the causes of sea-level rise. Another 3% of the extra heat enters the land surface, and merely 1% of the extra heat remains in the atmosphere causing the ~1 ^{o}C average global atmospheric warming in the past century.

OCEAN CHEMICAL CHANGES

The increasing CO_2 content of ocean waters, causes shifts in the chemical equilibria of the dissolved CO_2 system in seawater. Among the 3 different chemical forms in seawater, dissolved CO_2 (~1%), HCO_3^- (~90%, bicarbonate or hydrogencarbonate) and CO_3^{2-} (~10%, carbonate), the CO_2 and HCO_3^- both increase, but the CO_3^{2-} actually decreases. Latter decrease is a major concern with regards to the ability of many organisms for biocalcification, that is the biological production of shells and corals. With decreasing CO_3^{2-} it will become more and more difficult for the biota to produce the $CaCO_3$ of their shells and corals. In other words in the coming decades and centuries, the well-know tropical coral reefs (notably in the Caribbean including Bonaire, Saba Bank, St. Eustatius that are part of the Kingdom of The Netherlands) will be at peril. The same is true for the recently discovered deep-sea coral communities, and many shell-forming biota. Also as result of these shifts in the seawater CO_2 system, the nowadays alkaline oceans will become less alkaline, in other words the pH is decreasing (Figure 1) and hence the popular wording "ocean acidification".

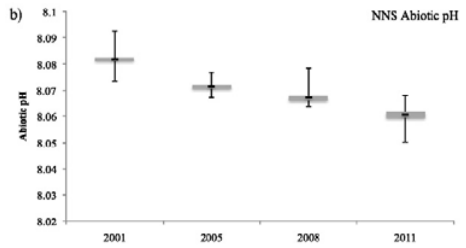


Figure 1. Decreasing pH in the Northern North Sea in decade 2001-2011, as result of changing chemistry of the CO_2 system in seawater. Based on once every 3 years time series cruise of RV Pelagia. The shown 'abiotic' pH value has been corrected for minor biological effects (Clargo et al., 2015, Marine Chemistry). Notice pH is still alkaline, the tipping point pH = 7 for the ocean becoming truly acidic will never occur, as such the popular wording "ocean acidification" may lead to confusion.

DISSOLUTION OF DEEP SEA CALCAREOUS DEPOSITS

The total CO_2 content of the oceans is enormous, some 150000 Petagram CO_2, as compared to 'merely' some 2500 Petagram of the greenhouse gas CO_2 in the atmosphere. Nevertheless, both reservoirs are now increasing due to extra fossil fuel CO_2. Over very long time scales of 100 million years, biogenic marine deposits of fossil $CaCO_3$ shells have accumulated at the seafloor. In terms of CO_2 storage, this represents the vast amount of 200 million Petagram. At those locations of the seafloor where these $CaCO_3$ deposits are in contact with deep ocean waters, the decreasing CO_3^{2-} in seawater will cause the $CaCO_3$ to slowly dissolve. For example, deep-sea mounts of deep-sea corals, that have heights of up to ~300m above the average seafloor depth, will begin to dissolve. Eventually deep sea coral ecosystems and mounds, discovered only ~25 years ago, may become extinct and disappear. In general the dissolution of fossil $CaCO_3$ deposits is deemed to take place over longer 1000 to 10000 years timescales, but will inevitably lead to further changes in the chemical composition of seawater. Hence good understanding of the nowadays deep-sea coral systems is essential to make long term predictions of the chemical state of the oceans. This in turn affects the chemical composition of the atmosphere, hence climate.

OCEAN BIOLOGICAL CYCLES

About half of the uptake of CO_2 from the atmosphere into the surface oceans can be attributed to marine photosynthesis, the fixation of CO_2 by uni-cellular marine algae (phytoplankton). This is the "biological pump" for pumping CO_2 out of the atmosphere. The remaining CO_2 uptake from the atmosphere is by abiotic processes, notably winter cooling in (sub)polar waters that at lower temperature become undersaturated, hence more CO_2 enters from air to sea. For phytoplankton to grow, several more chemical elements are required. Next to CO_2 all algae need the major nutrients Nitrogen and Phosphorus, and the key group of diatom algae also need Silicon for constructing their external 'skeletons' or frustules. These major nutrients are measured with top accuracy by the Nutrients Facility of The Netherlands, serving the community by taking part in ocean cruises aboard own vessel Pelagia as well as vessels of other, mostly European, nations.

BIO-ESSENTIAL TRACE METAL ELEMENTS

Less well known is the fact that all living organisms, hence also all marine algae, require minute amounts of trace metal elements, for a variety of biochemical functions. These bio-essential trace metal elements are, in order of importance, iron (Fe), zinc (Zn), manganese (Mn), cobalt (Co), nickel (Ni) and copper (Cu). Iron is crucial in the photosystem of the plant cell, and in many other biochemical functions. All 6 metals have key roles as co-factors of various enzymes within the cell. Scientists of The Netherlands were among the first (1988) to demonstrate that the ecosystem of the vast Southern Ocean is limited due to lack of dissolved Fe. This also hampers the biological pump. We now know that elsewhere this also is the case, overall in ~40% of the world oceans. The next step is the unraveling of the ocean cycling of Fe and the other trace metals.

GEOTRACES

Scientists of The Netherlands were among the founders (2006) of the international GEOTRACES program, for measuring the worldwide 3-D distributions of these 6 bio-essential trace metals, as well as many other trace elements and their isotopic composition (www.geotraces.org). This new frontier of worldwide mapping is now well underway using novel instrumentation (Figure 2). The NIOZ coordinated the first GEOTRACES efforts, taking place in the Arctic and Antarctic Oceans during the 2007-2008 International Polar Year. Since then scientists of The Netherlands have done major suites of measurements (2010-2011) in the entire West Atlantic Ocean, along 17500 kilometers, at ~5km depth, from Iceland to the Falklands (Figures 3, 4). More recently trace elements were measured in summer 2013 in the Mediterranean Sea, in the anoxic waters of the Black Sea, and in summer 2015 at the geographic North Pole and surrounding region. Findings also include some pollutant trace metals that did hardly, or not at all, occur in the pristine pre-industrial oceans. These are dissolved lead (Pb) due to the worldwide use of leaded gasoline, and mercury (Hg) from a suite of industrial sources, as well as illegal gold-mining. Both Pb and Hg have major emissions into the atmosphere, and hence a wide global distribution for depositing into the oceans. Cadmium is known as a pollutant as well, but in the oceans we hardly see any increase, because most pollutant Cd does deposit in the sediments of estuaries and coastal seas. Cutting-edge highly accurate determinations of the stable isotopic ratio values of Cd, as well as Fe, Zn and other trace metals in seawater are now beginning. Observed isotopic shifts provide constraints in support of unraveling their biogeochemical cycles in the oceans.

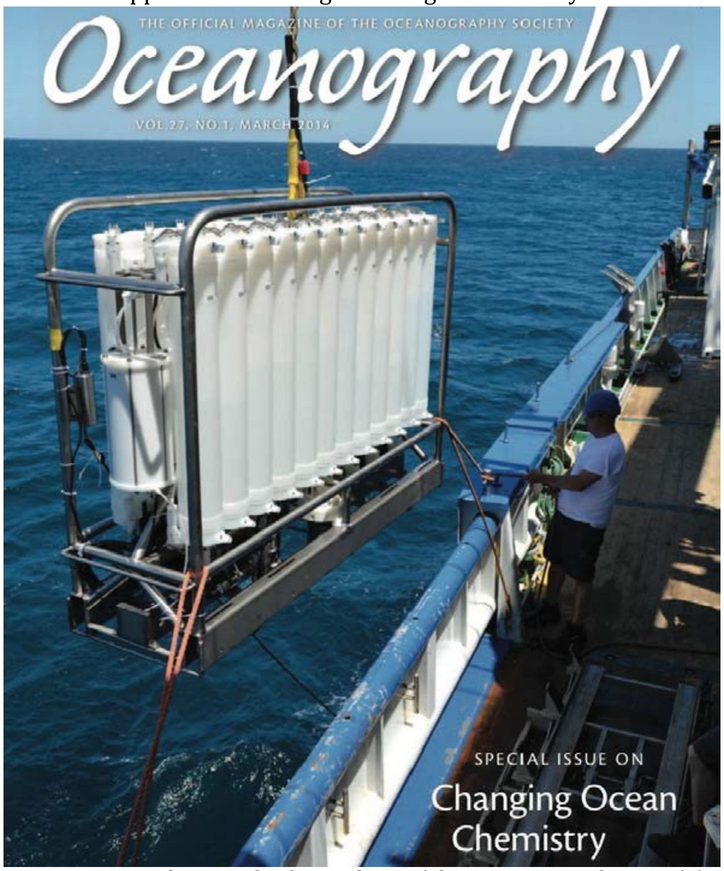


Figure 2. Cover Photograph of special issue 'Changing Ocean Chemistry' (March 2014) showing deployment into the deep sea of the novel ultraclean sampling system for trace metal elements deployed from RV Pelagia. The unique system developed at Royal NIOZ comprises 24 ultraclean PVDF plastic samplers of 22 L each, mounted on a Titanium frame devoid of iron and all other metals being investigated, and deployed from a Dyneema synthetic cable (23 mm diameter, 9000 m length) with internal signal and glassfibre cables. Photograph taken during West Atlantic GEOTRACES campaign in 2010. (Rijkenberg et al, 2015, Marine Chemistry, 177, 501-509; Middag et al., 2015, Marine Chemistry, 177,476-489)

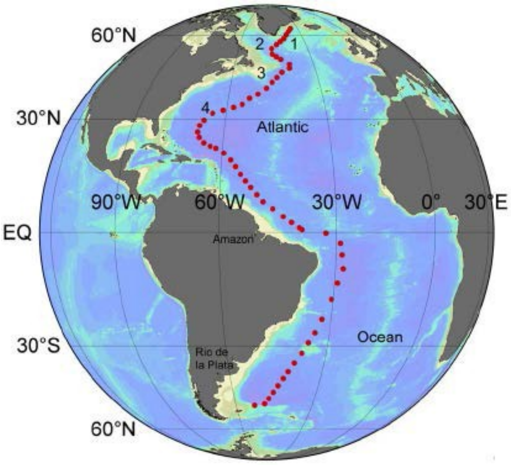


Figure 3. The 17500 km long section, comprising60 full depth stations, of 24 sampling depths each, covered the complete West Atlantic Ocean. The cruises 64PE319 and 64PE321 aboard RV Pelagia and cruise 74JC057 of UK RV James Cook (by European exchange arrangements of research vessels). Figure taken of Rijkenberg et al. (2014) PLOS ONE.

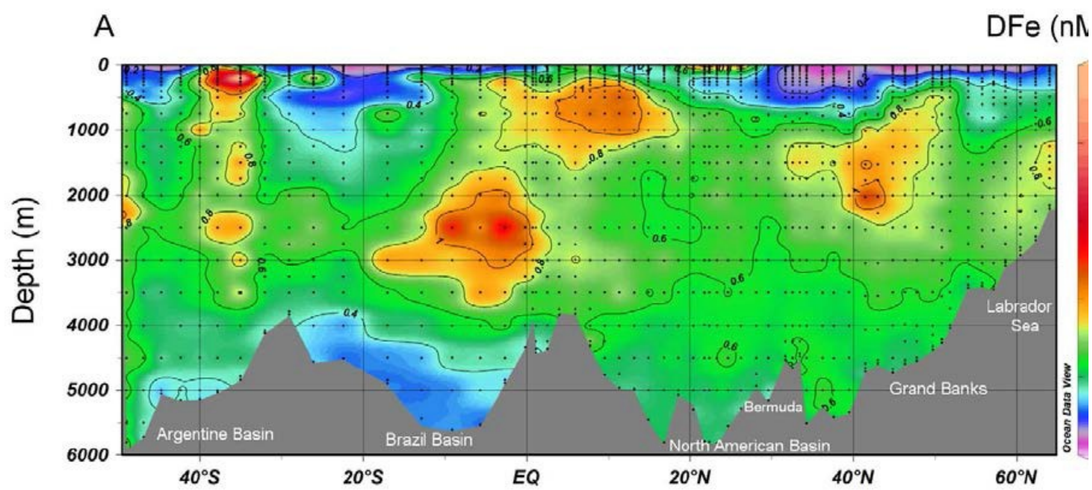


Figure 4. Dissolved iron (Fe) in very low concentrations (nM = 10^{-9} mol/Litre), contour plot based on ~1400 data values (black dots). Please notice very low Fe (purple) in surface waters of temperate regions. The higher values in susbsurface waters (~1000m depth) at the Equator are due to Fe dissolution in the low oxygen waters. The other maximum at ~2500m depth just south of the Equator due to hydrothermal input from submarine hydrothermal vents at the Mid Atlantic Ridge. Figure taken of Rijkenberg et al. (2014) PLOS ONE.

Outstanding Science Questions (incl. NWA, nationale wetenschapsagenda)

The increase of CO_2 in atmosphere and oceans is one of the most dramatic changes taking place now. Regular repeat observations of increasing CO2 in the oceans are essential, every 5-10 years in key ocean regions. For this a modern worldwide fleet of research vessels is pivotal. The effects of the changing chemistry of the ocean on biota, notably tropical coral reefs and deep-sea corals, need to be investigated, this field-work also requiring a safe and reliable ocean-going vessel.
For the role and ocean biological cycling of (bio-essential) trace metal elements, much progress has been made thus far in context of GEOTRACES. However, we know or suspect myriad interactions of these trace metals with the major nutrients, N, P and Si, as well as with dissolved CO2. For example in a specific

enzyme one trace metal element may substitute for another that is in poor supply. Also there are some observations that under limitation of Fe there evolves superoxide radical within the cell, superoxide is very destructive, upon which the algae take up more Mn for producing the enzyme SuperOxide Dismutase (SOD) for their protection by annihilating the superoxide radical. The decreasing pH of seawater also causes shifts between different chemical forms of a trace metal in seawater, where one form may be more, or may be less, bioavailable than the other. All this affects the growth and biomass of algae, the base of the marine foodweb, and hence all living organisms in the sea. Thus while progress is made, sometimes impressive, we are very much aware that we are only beginning to "scratch the surface" of these interactions in the vast, deep, majestic world oceans.
As mentioned most research programs of ocean biogeochemistry are European joint ventures, where collaborations exist with leading institutes both within The Netherlands and in Britain, Germany, France, Norway, Sweden, Switzerland.

Within The Netherlands there are collaborations for the Ocean Carbon Cycle with excellent colleagues of universities of Groningen, Utrecht. Deltares is interested to set up a new collaboration. For trace elements work is done both at NIOZ and in Utrecht.

<u>University of Groningen</u>
- Energy and Sustainability Research Institute Groningen (ESRIG)
  - Centre for Isotope Research, on ocean carbon cycle; Prof. Harro Meijer
  - Department Ocean Ecosystems, on plankton interaction; Prof. Anita Buma
  - Centre for Energy and Environmental Sciences; Dr. Elizabeth Jones

<u>University of Utrecht</u>
- Earth Sciences;
  - Prof. Jack Middelburg, on ocean carbon cycle;
  - Prof. Caroline Slomp on trace metals cycling in low-oxygen and sulfidic basins.

ICOS- Netherlands/ International Carbon Observing System includes VU, WUR, UU, NIOZ, RUG

<u>Belgium</u>
Laboratoire G-TIME (Geochemistry: Tracing by Isotopes, Minerals and Elements) Université Libre de Bruxelles;
Laboratoire de Glaciologie (GLACIOL), Université Libre de Bruxelles;
Ecologie des Systèmes Aquatiques, Université Libre de Bruxelles;

<u>Britain</u>
- British Antarctic Survey, carbon cycle, trace metals
- National Oceanography Centre Southampton, University of Southampton; GEOTRACES
- University of Plymouth; GEOTRACES
- University of Oxford, GEOTRACES
- University of East Anglia, ocean carbon cycle
- University of Exeter, ocean carbon cycle

<u>Germany</u>
Alfred Wegener Institut fur Polar- und Meeresforschung;
ocean carbon cycle, major nutrients, trace metals
GEOMAR, Helmholtz Centre for Ocean Research, Kiel
Max Planck Institute, Mainz; stable isotopes of Cadmium.

<u>France</u>
- University of Brest; trace metals
- Laboratoire d'Etudes en Géophysique et Océanographie Spatiales Observatoire Midi-Pyrénées (LEGOS-OMP)Toulouse; GEOTRACES

Norway
Geophysical Institute and Bjerknes Centre for Climate Research, University of Bergen; ocean carbon cycle

Spain
University of Las Palmas de Gran Canaria, Spain; ocean carbon cycle
Universitat Autònoma de Barcelona; GEOTRACES

Sweden
University of Goteborg; ocean carbon cycle

Switzerland
ETH, Zurich; stable isotopes of Zinc
ETH Zurich; ocean carbon cycle

Theme 2: Seafloor processes

The deep sea is often considered to be a 'last wilderness on earth', suggesting that its ecosystems are still in a pristine state. However, the human imprint on the deep sea is sharply increasing. Deep fish populations are impacted most notably by bottom trawling. The hydrocarbon industry is expanding into the deep sea, placing installations on the seafloor, disturbing the sediment and increasing turbidity during exploration drilling with the chance of large-scale disasters such as the blowout of the Deepwater Horizon oil rig in the Gulf of Mexico. More recently, interest has grown for the mining of minerals from the deep seafloor, such as manganese nodules or sulphide deposits. Deep-sea mining will disturb and disrupt deep-sea ecosystems at an unprecedented spatial and temporal scale. This expansion of anthropogenic activities clearly indicates that we are transiting from the era of "deep sea exploration" into the era of "deep sea exploitation".

In addition to the expansion of anthropogenic activities towards the deep sea, the deep seafloor is also not immune to global changes. One major insight from the last 20 years is that ecosystems in the deep sea are much more dynamic than previously anticipated and respond within time scales of weeks to months to seasonal and climatic variation at the ocean's surface. Moreover, the anticipated shoaling of the aragonite saturation horizon due to ocean acidification will expose vulnerable ecosystems such as cold-water coral reefs to under-saturated waters already within the next decades.
Marine protected areas and marine spatial planning is required to manage the increased anthropogenic use of deep-sea resources. In addition, information on the functioning of unique marine ecosystems is critically needed to inform policy-makers. It is clear that a scientific basis is critically needed to analyse and predict how deep-sea ecosystems will respond to these multitude of stressors.
A combination of novel monitoring systems with targeted experimentation will be needed to address the various examples of human-induced changes to ocean ecosystems. To first determine natural variability and monitor these anthropogenic induced changes, an integrated ocean observatory is needed, which consists of several coupled moored observatories that are connected with crawlers and a Remotely Operated Vehicle (ROV). Long-term monitoring will allow to measure changes in our oceans ranging from the short time scales (hours-months) to longer time scales (years to decades). To measure and define processes that occur in the benthic boundary layer at the interface between water and sediment a ROV is needed, which can provide high-resolution data on spatial mapping and will allow to carry out focused experiments (e.g. fluxes between water and sediment). The ROV will be used in combination with the observatory, which will act as a docking station. The observatory also acts as docking and energy charging station for an AUV, which can map in a relatively short period the surrounding area multiple times. This mapping includes environmental data, as well as, terrain mapping and photographing.

Most facilities currently used at sea only measure snapshots in time. Stand-alone multifunctional observatories will provide the opportunity to collect data over longer timescales to monitor in situ natural and anthropogenic variability. Real time data transfer will in addition allow smart sampling (e.g.

change of sample interval). Since it is hard to carry to experiments in the laboratory that mimic deep sea environments, ROV and crawlers will in addition provide the possibility to carry out in situ experiments for instance near deep-sea reefs.

(Permanent) observatory, consists of multiple moored observatories (e.g. moorings and/or landers) that are equipped with a multitude of instruments to monitor near bed variability as well as variability within the water column. These moored observatories are connected by cables and will be connected via a docking station to a surface buoy that will transfer real time data to shore, not only allowing for data transfer, but also allowing change of sampling scheme when needed or when changes are observed that need to be monitored at higher resolution. The surface buoy can also be equipped with additional meteo-sensors. Crawlers will drive around the observatory allowing for high resolution mapping with camera's but also for repeated sampling in the vicinity of the observatory. They can base at one of the landers, to charge battery power and transfer data.

Within the Netherlands groups working on deep sea floor processes are mainly at NIOZ, Utrecht University and WUR.

Prof. Dr. J.M. Middelburg (University of Utrecht)
Dr. D. van Oevelen (NIOZ)
Prof. Dr. A.J. Murk (WUR)
Dr. F. Mienis (NIOZ)

Theme 3: Marine Microbiology and Microbial Geochemistry

Earth contains more than 10^{30} living microbes and approximately half of them thrive in marine ecosystems (e.g. oceans, shallow seas, tidal flats, deep marine sediments, sea ice, hydrothermal vents, etc.). Together, the combined metabolisms of these vast numbers of marine microbes influence our climate, and the functioning of the entire globe. They are of key importance in sustaining the geochemical cycling of elements (e.g. carbon, nitrogen, sulfur) through essential processes including photosynthesis, respiration, chemoautotrophy, and nitrogen fixation. Without these microbes, life of higher organisms (including humankind) would be impossible. Yet, although they are of global importance, our knowledge on the identity of these microbes, their functioning, interactions, and global dynamics is extremely limited.

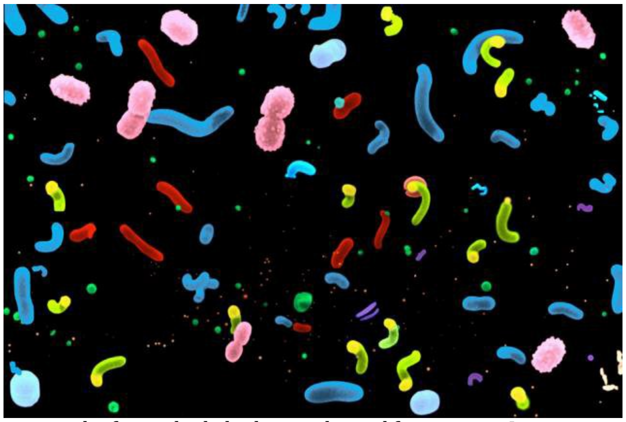


Fig. 5 Scanning electron micrograph of microbial plankton, colorized for contrast. Image courtesy Ed DeLong and David Karl

Outstanding science questions

The diversity of microbial life in the ocean is extremely high and spans all known groups of Bacteria, Archaea, microbial Eukarya, and viruses. However, this diversity is highly under-sampled and a thorough understanding of the identity, physiology, and interactions of marine microbes is a major field of research where progress is urgently demanded. The past decade has witnessed an explosion of DNA sequencing technologies that provide insights into (marine) genome sequences, the blueprints of Life. The analysis of environmental genomic information by metagenomics can now even be deployed on marine vessels with real-time field-sized short- and long-read DNA sequencing technologies, facilitating the characterization of the real diversity and genomic potential of marine environments. Moreover, other biomolecules such as proteins (proteomics), intact polar lipids (lipidomics), and small metabolites (metabolomics) enable the correlation of genomic data with important metabolic intermediates and end-products, disclosing a wide range of potential applications. Such high-throughput approaches will have to be used in tandem with other techniques (such as culturing and isotope labeling in combination with nano-SIMS, bioinformatics and computational modeling) to decipher the physiology, interaction networks, and role in the biogeochemical cycles of marine microbes in their natural ecosystems. The oceans are complex systems that profoundly influence our planet, and the marine microbiome is critical to its health status and functioning. Really understanding this unseen microbial world will, ultimately, allow us to exploit these microbes in challenging issues such as mitigating climate change, production of biofuels, deep sea mineral exploitation, and discovery and production of new medicines and valuable natural products. Moreover, understanding the global distribution of marine microbes and their genes will allow us to make prospective models of the spread of pathogens and their traits, including antibiotic resistance.

These research questions fit well in the recently published Dutch Science Agenda. Specifically, they relate to the two following questions:

1) What is the role of microbes in ecosystems and how can they be used for improving health and environment? (question 5)
2) How can the water be carefully managed in the future? (question 11)
3) How do seas and oceans function and what is their future impact? (question 12)
4) How can we get a grip on the unpredictability of complex networks and chaotic systems? (question 123)

Research setup

To effectively study the identity and physiology of marine microbes, appropriate sampling of diverse and remote marine environments will be required. This will not only allow “omic” methods to be applied but will also allow to obtain starting material for the set-up of enrichment and pure cultures. At the same time experiments within the marine water column or sediments will have to be performed “in situ” (such as labeling experiments) in combination with environmental microbial monitoring to explore whether our typical “snapshot” approaches are valid to make generalizations on an ocean and longer time scales. Finally, only longer-term field experiments can provide the invaluable input data for realistic bottom-up computational modeling of marine ecosystem dynamics that integrate and make sense of the large “omics” datasets.

NMF requirement

For such endeavors it is essential that Dutch marine microbiologists have access to a modern, fully equipped, ocean going research vessel that will allow sampling of remotely accessible marine ecosystems such as anoxic basins, the deep sea, abyssal sediments, and mid ocean ridges. Instrument development for in-situ measurements and their application will also remain an important tool enabling progress to be made in this research field.

Dutch scientists involved in this theme:

Prof. Dr. Ir. J.S. Sinninghe Damsté (NIOZ/University of Utrecht)
Prof. Dr. C. Brussaard (NIOZ/University of Amsterdam)
Prof. Dr. J. Huisman (University of Amsterdam)
Prof. Dr. Ir. M.S.M. Jetten (Radboud University)
Prof. Dr. F. Meysman (NIOZ/Free University of Brussels)
Prof. Dr. J.J. Middelburg (University of Utrecht)
Prof. Dr. G. Muyzer (University of Amsterdam)
Prof. Dr. B. Snel (University of Utrecht)
Prof. Dr. L. Stal (NIOZ/University of Amsterdam)
Prof. Dr. Ir. A.J.M. Stams (Wageningen University)

Theme 4: Research in Underwater Archaeology and Underwater Cultural Heritage Management

Intro/State of the Art

Nowadays there is more water than land surface on this planet. Over the last ten-thousands of years, sea level rise has cause vast amounts of areas to become inundated. Evidence of early inhabitants and migration patterns could be found under meters of water and layers of deposited sediments. A good example is 'Doggerland' in the North Sea: former land between the Netherlands and England that hosts the oldest (Neanderthal) remnants of human beings in the area (Gaffney et al 2007).

Then it was still land, but the people in the Netherlands have also a long relationship with the sea. Maritime archaeology studies this relation between people and the sea from the material resources.

The water – river, lakes and especially the sea - are part of our identity. This has resulted in a long tradition in using the sea for connecting cultures, markets and fighting wars. This in return has resulted in many often century shipwrecks old shipwrecks of Dutch origin being found on the seabeds all over the world (Manders& Maarleveld 2006).

Being so important for our past, the Netherlands claims the ownership of wrecks of the Eastindian Company (VOC), Westindian Company (WIC), the Admiralty and other subsequent navy vessels. These are sovereign properties. Responsibilities for the management are lying (at least for a part of it) at the Dutchgovernment.

However, due to the hostile natural environment, we have long been struggling with how to take up the responsibilities of our underwater cultural heritage and also on how to answer the many scientific questions we have. Due to new developments in techniques we may now come close to fulfil these responsibilities and also to learn more about our past. The wrecks represent our efforts to discover the world and the oceans as the last frontier. They form part of our identity as a maritime nation.

Figure 6. At large depths, hundreds of years old shipwrecks can sometimes be of remarkable preservation.

Outstanding Science Questions (cf ook NWA, nationale wetenschapsagenda)

At this moment the new National Research Agenda for Archaeology (NOAA 2.0) is being developed. Overarching scientific research questions are focussed on the adaptation of early hominids to climate change, but also the use of water as a means of transport, way of living and as a battlefield. The core thus is adaptation to water by societies and vice versa: changing the environment to suit society.

Other important research questions are related to get insight in the post-depositional processes around shipwrecks in different environmental areas underwater, to get better insight in the unknown resources underwater (not yet discovered sites, often buried within the sediment) and ways to preserve underwater archaeological sites in situ with keeping in mind the multiple values of a wreck site. Wrecks may pose threats, but also can be beneficial for the natural environment.

Researchlogistics
A mapping of the seabed, the seabed surface and the first 20 meters within is needed as a basis for research. This can be executed in pinpointed areas. For prehistoric landscape research areas up to 50 meters of water depth need to be addressed. For this it might be necessary to use a shallower boat equipped with the necessary equipment and/or an AUV. The seabed surface may be mapped with side scan sonar (e.g. 4125 Edgetech) and Multibeam (e.g. Seabat T20-s has a high resolution and can be mounted on an AUV and is suitable for larger depth). Within the sediment subbottom profiling (preferably the new 3D generation, e.g. the parametric transducer array that has been designed and manufactured by Innomar Technologie Gmb) can be used. Sediment coring not only reveals geological build-up of the area, but also can be used for sampling the seabed on human related matter and for Optical Stimulated Luminiscence Dating (OSL).
For the shipwrecks (also at large depths) the same equipment can be used, which can be complimented by a magnetometer (e.g. Geometrics) and video/photo camera mounted on a ROV or AUV. New developments give us the opportunity to create on scale 3D models of shipwrecks on the seabed. This again allows us to investigate the wrecks in more detail on the surface and to develop methods for in situ protection or (if required) excavation strategies.

NMF requirements
- AUV/ROV to large depths (minimum of 1000 m)
- Side scan sonar (for shallow waters and high depths. Preferably Edgetech. High resolutions are very important)
- Multibeam (newest models, high resolution and one that can be mounted on AUV for shallow and deep water. High resolutions very important)
- 3d subbottom profiler (parametric transducer array that has been designed and manufactured by Innomar Technologie)
- High resolution film & photocameras that can be mounted on ROV or AUV up to a minimum of 1000 m depth.
- Extended piston corer with a penetration of at least 20 m, with isolated sub-sampling system allowing OSL research.

National cooperation - In the light of new developments in multidisciplinary research and management on national, European and worldwide level new research is focussed on the cooperation between multiple stakeholders with different values to protect. At the moment cutting edge research is being conducted to identify different values of shipwrecks and to develop management plans to suit these different stakeholder groups.
Shipwrecks for example may have a high cultural historical significance, but due to being hard substrate on a generally sandy seabed, these wrecks also have value for the biodiversity. Shallow wreck sites may – besides cultural value – also have value for dive tourism. We therefore not only seek for cooperation within the archaeological community but also within the expertise of geology, biology, climate and e.g. environmental studies (Manders 2015).

Possible Cooperation:
- University of Leiden (UL)
- University of Amsterdam (UvA)
- University of Groningen (RUG)
- University of Utrecht (UU)
- Cultural Heritage Agency of the Netherlands (RCE)
- TNO/Deltares
- NIOZ
- Periplus/Archeomare
- SABARC (SABA)
- SECAR (St Eustatius)
- NAAM (Curacao)
- Priority Shared Heritage Countries: Japan, Sri Lanka, Australia, US, Brazil, Russia, South Africa, India, Indonesia, Suriname.
- Countries with Dutch shipwrecks within their waters.

Theme 5: Paleoclimate research

Introduction & State of the Art

Current climate is unmistakable changing due to the high amounts of anthropogenic greenhouse gas emissions. Sea level will rise and temperature and precipitation patterns will change considerably with respect to the regular glacial-interglacial pacing over the last millions of years. The only way to predict future climate change is by climate modelling. These models are currently evaluated by a thorough comparison with past climate data. Paleoclimate data provide a wealth of information regarding the functioning of the ocean-climate system and ecological response. In the past decade, paleoclimate investigations have stimulated the development of new proxy data that became more and more accurate to constrain current climate models. At the same time, the development of high-resolution climate models has increased, which makes it possible to investigate also regional features in the climate system and its response to climate change. Because of this latter development, it will become possible, and necessary, to collect paleoclimate data from a much more constraint area to verify the outcome of these new generation of model simulations and hence to increase the predictability of the climate system for the coming centuries. The best sediment records are those in the marine realm as they provide continuous records of ocean conditions over millions of years. The major scientific challenge is to down-scale paleoclimate investigations from a global to a system- and regional scale resolution in order to test the robustness of high-resolution climate models.

Reconstruction of past climate is based on so-called proxy relationships in which measurable variables are calibrated against environmental parameters. Ideally, a certain property of a fossil remnant, often its chemical or isotopic composition, is a unique function of the parameter that needs to be reconstructed.. However, the accuracy and precision of these proxies is compromised by uncertainties regarding the influence of climate or chemical parameters other than the climate variable aimed for. Hence, there is a continuous need for improving proxies and constraining uncertainties. Moreover, the quest for new proxies, which are less compromised or compromised by different processes and, therefore, more accurate or complementary, continues. For several important paleoclimate variables no proxy exists and thus no quantitative information is available. There is for example a lack of insight in atmospheric methane variations before the ice core record and therefore no insight in sources and sinks of methane in periods where the Earth was substantially warmer. Improving proxies is generally done by obtaining a fundamental understanding of the correlation between climate parameter and proxy value and constraining the impact of parameters other than the desired climate parameter on the proxy value. New proxies can potentially be developed by examining organisms or (geo)chemical tracers which are known to change in composition when a certain climate parameter is changing. To perform this research it is essential to have access to ocean going facilities in order to collect not only material for proxy calibrations but also to obtain sediment records which reveal climate changes over the last thousands to tens of thousands of years.

Research logistics

In order to reconstruct recent climate change we need to collect sediment records from different parts of the ocean. These records are from both tropical and temperate regions and coastal and open ocean to cover a large spatial gradient and test new high resolution climate models, especially in regions identified by these climate models as critical.

The calibration of proxies can partly be achieved by laboratory experiments such as culturing of microbes. However, all proxies need to be tested, validated and calibrated in the natural environment, i.e. the present day ocean. This can be achieved by collecting the different proxy carries in parts of the ocean where a natural gradient in environmental parameters such as temperature, salinity, oxygen concentration, trace metals, etc. exists.

NMF requirements

The research described above requires not only shiptime to recover sediment records but also advanced equipment to monitor the behavior of physical parameters and to collect proxy carriers such as organic matter, foraminifera, corals and algae.

Sediment records can be obtained using piston coring which can yield sediment records covering the late Quaternary. For deeper drilling, and thus older records, the Netherlands has access to drilling ships such as the JOIDES Resolution, through its membership of the International Ocean Discovery Program. However, future Dutch drilling programs should make use of drilling robots, such as the German-developed MEBO-2, which can independently drill for hundreds of meters in the sea floor. It will yield unprecedented paleoclimate archives with which new data can be generated to test high-resolution climate models. This start-of-the-art equipment still requires a ship to position the drilling robot and to recover the core material.

To calibrate proxies we need to collect diverse proxy carriers from different parts of the water column and ocean floor. Plankton and microbes need to be collected by nets and in situ pumps. Multiple sediment traps need to be deployed to collect settling material over a full seasonal cycle. Box cores will be used to collect surface sediments, representing the deposition over the last centuries, containing the most recent climate signal. Besides traditional methods we envisage for the future also autonomous underwater vehicles, such as those developed at MBARI (USA), which collect the different proxy carriers in the water column as well as from the surface sediment.

List of Dutch researchers involved in this theme

The Dutch paleoclimate community has a long record of outstanding collaborations, especially visible in the former Darwin Center for Biogeology and now in the Netherlands Center of Earth Sciences (NESSC; www.nessc.nl). In these centers geologists collaborate with biogeochemists, microbiologists, climate modellers and physical oceanographers. Below is a non-exhaustive list of Dutch scientist working on the topics described here.

Royal Netherlands Institute for Sea Research
Jaap Sinninghe Damsté
Stefan Schouten
Gert-Jan Reichart
Jan-Berend Stuut
Lennart De Nooijer
Geert-Jan Brummer
Marcel van der Meer

Free University of Amsterdam
John Reimer
Gerald Ganssen
Frank Peeters

University of Utrecht
Appy Sluijs
Luc Lourens
Caroline Slomp
Martin Ziegler
Henk Brinkhuis
Peter Bijl
Jack Middelburg
Francien Peterse
Francesca Sangiorgi
Bas van de Schootbrugge
Gert de Lange

Theme 6: Multiple Scale Physical Oceanography

Introduction and State of the Art

The Netherlands is historically famous as sea-going nation (*Dutch Glory!*). Partly as a result of this history we have often been (co-)leading in international oceanographic programs, e.g. in the LOCO and ACSEX programs. These programs have led to a breakthrough in our understanding of mixing of internal waves and the structure of inter-ocean exchange processes around Africa and through the Antarctic circumpolar current. Those exchange processes play a crucial role in large-scale climate variations. Possession of a national ship assures access to international programs as a full partner.

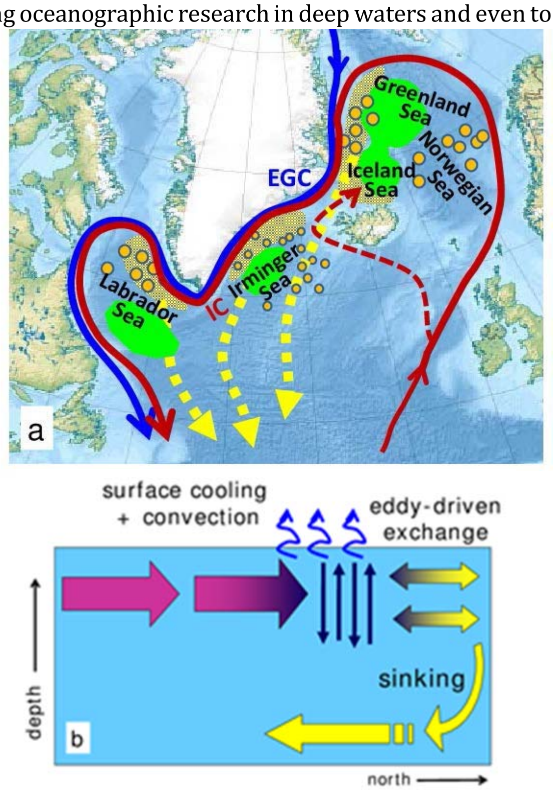
For observing and monitoring of process studies in general, and mixing and turbulence in particular, ships are necessary for a number of reasons, such as:

1. Lagrangean floats are expelled from boundary currents such as the Gulfstream and all regions having high shear. These are exactly those kind of regions that show the largest water transports, mixing from small to large scale and vice versa, and rectification processes;
2. Research concentrates ever more on larger complexities and to this end an optimum use of coupling with adequate in situ measurements is a necessity. Ships form an integral part of such observations, and

3. The ocean circulation is by and large built up of a number of cycles with various temporal and spatial scales constituting the connections between the cycles. In modern oceanographic research, processes are being studied that dominate the leaking components from small to large scales and vice versa. Ships remain essential for these.

Outstanding Science Questions and Research Setup

For the Netherlands, the issue of dynamical sea level rise is one of the most pertinent reasons to continue doing oceanographic research in deep waters and even to extend such efforts (see Figure 7).



Figuur 7: (a) Schematic of the North Atlantic Ocean and its marginal seas depicting warm (red) and fresh (blue) surface flows and dense subsurface flows (yellow). Eddy activity (orange), convection regions (green) and anticipated main sinking regions (hatched yellow) are indicated [EGC: East Greenland Current, IC: Irminger Current, dashed red line: eddy-driven flow proposed by Våge et al (2013)]; (b): Schematic side view of the Atlantic Meridional Overturning Circulation (AMOC) and processes governing sinking. (Courtesy: Caroline Katsman)

Scale interactions between turbulent eddies and large-scale current structures and their (climate-induced) variations are important aspects of present and future ocean research. Most interesting are the interactions in westerly and easterly boundary currents which can be regarded as jet streams with turbulent eddies as storm tracks. A successor of the *Pelagia* would enable Dutch researchers to do comparable kind of observations to the westerly boundary currents in the Carribean and futher north the Gulf Stream. Especially important is also the easterly boundary current along the European continental shelf. Changes in this current are important for low-frequency variations in sea level of the North Sea, the exchange of turbulent eddies and boundary currents for high-frequency variations in sea level of the North Sea and changes in those interactions that can be related to changes in the spectrum of sea level change for the Dutch coast.

NMFrequirements

A successor of RV *Pelagia* is necessary for studying turbulent mixing processes in oceans and seas, many of these in connection to large scale structures as internal wave patterns, eddies, etc. This requires a multidisciplinary approach to study the spreading of particle substances and physical effects on sea life. In-situ physics observations are mandatory for a wide variety of ocean studies, ranging from the large-scale circulation to turbulent exchange processes. Although much is still to be learned from physical dynamics viewpoint, the studies are important for a better understanding of the transport of matter, nutrients and, eventually, ocean life. A truly multidisciplinary approach is thus needed. The core of such studies focuses on the turbulent mixing processes associated with large-scale structures like (meso-scale) eddies, internal wave patterns including their generation and breaking. Turbulence is still one of the least understood major physical problem.

NL Cooperation
The four most important beneficiaries within The Netherlands are NIOZ, IMAU, TU Delft and KNMI.

Theme 7: Marine Geology

The Earth is covered by water for nearly 70% and of that area less than 5% has been mapped with an accuracy comparable to maps existing of the surface of the planet Mars. We literally know more about the surface of the moon than of the sea floor. The main reason for this is that sea water blocks electromagnetic radiation and that exploration of the sea floor almost uniquely relies on acoustic methods. Only by using AUVs and/or ROVs, which are able to get close to the seafloor, the sea floor can be investigated with an accuracy similar to satellite observations. Lack of resolution and large unexplored territories underlie the still frequent surprising discoveries in Marine Geology. For example, the fact that cold water corals sea mounts are a major feature of the deep sea, and the impact of deep sea canyons on transport from the shelf to the deep sea are findings of the last decade only. New discoveries of deep-sea ecosystems are literally made every day.

Outstanding science questions
Models for sediment transport, bed forms and grain size are mostly based on relating water column data to observations made at the sea floor. Such models are almost always largely empirical. The reason for this is that the actual processes impacting the sediment are happening at or just above the seafloor and hence difficult to observe from a ship using equipment lowered on a cable. These processes need to be studied in great detail, over longer time scales and with a higher spatial resolution than hitherto accomplished in order to develop a truly mechanistic understanding. Such observations rely on the application of autonomous sea floor landers equipped with the relevant sensors. Such landers are being developed at Royal NIOZ and the lander group is a world leader in designing and applying equipment for deep-sea observation systems.
The impact of early diagenesis at the seafloor and exchange of organic and inorganic substituents with the water column is largely unknown. Still, for processes such as the buffering of excess CO_2 by enhanced calcium carbonate dissolution this exchange is essential. Also in so-called dead-zones, where recent deoxygenation has changed the geochemical equilibria, the remobilization of elements from the sea floor likely has a large impact on the biogeochemical cycling but is unknown. Investigating these processes requires high resolution in situ analyses, preferably over longer time scales.
Within the water column the exchange between particles, either river transported, blown in as desert dust or derived from planktonic productivity, has a profound impact on the biogeochemical cycling. Iron desorbed from dust particles is probably the main source for this bio-essential micronutrient. As a consequence of the ongoing changes in the marine environment (warming, acidification and deoxygenation) the exchange between these particles and sea water is probably changing, which in turn will heavily impact global biogeochemical cyles. In addition, it has been shown that there is a strong link between ocean currents and atmospheric climate zones feeding back on each other as well as on sediment input from land. As a consequence, a change in sediment supply is anticipated as a consequence of ongoing global climate change.
Although studies targeting biomineralization have made major progress through controlled growth experiments during the last decade, extending these findings to the natural environment remains essential. Sediment traps, dust collecting surface buoys in combination with in situ sensors are able to provide such data. In the Netherlands (both at UU and NIOZ) there is worldwide recognized experience with both sediment traps and observational buoys, which could only have been established using the existing ocean-going facilities. To preserve this pole position in marine sciences we need to invest in a marine platform that can handle such large equipment.

To combat global climate change it has been suggested to speed up natural occurring processes such as ocean fertilization with desert dust. The idea that so-called geo-engineers advocate is that natural uptake of the greenhouse gas CO_2 can be enhanced by artificially stimulating phytoplankon blooms in the open ocean and thus speed up the global Carbon cycle. However, financial- rather than philanthropic views drive these ideas and the risks for the global ocean, ecosystems, and e.g., fishing grounds are largely neglected. Already, large-scale ocean fertilization experiments have successfully been carried out and as a result of their (apparent) success will most likely be followed-up. The only capable body to objectively study the effects of such experiments is the international scientific community.

This research fits well with the following questions in recently formulated Dutch Science agenda:

1) How do ecosystems (including oceanic ones) work and how sensitive are they to environmental changes (including human-induced ones)? (question 4)
2) How is climate changing, including extreme weather conditions and what are the consequences? (question 8)
3) How can we make better use of the global Carbon-, Nitrogen-, and Phosphorous cycles? (question 9)
4) How do seas and oceans function and what is their future impact? (question 12)

Research setup

Addressing the above formulated research questions relies on in situ measurements and/or collection of time series of fluxes (both sediments and chemicals). The use of landers, buoys, moorings, and AUVs will enable the scientific community to capture more than snap shots of the processes of interest. Although such time-series monitoring approaches are less "shiptime" intensive by using autonomous systems, still a research vessel that is able to deploy and recover the appropriate and to be developed equipment remains essential.

Dutch scientists involved in this theme:
Prof. Dr. G.J. Reichart (NIOZ/University of Utrecht)
Prof. Dr. G.J. Brummer (NIOZ/Free University Amsterdam)
Prof. Dr. C. Slomp (Utrecht University)
Prof. Dr. J.J. Middelburg (University of Utrecht)
Dr. J.B. Stuut (NIOZ/MARUM Germany)
Dr. L.J. de Nooijer (NIOZ)

Theme 8: Scientific collaboration with the private and public sector

Blue Growth is the long term strategy to support sustainable growth in the marine and maritime sectors as a whole. Seas and oceans are drivers for the European economy and have great potential for innovation and growth. It is the maritime contribution to achieving the goals of the Europe 2020 strategy for smart, sustainable and inclusive growth. The 'blue' economy represents roughly 5.4 million jobs in Europe and generates a gross added value of almost €500 billion a year. Close collaboration between the industrial partners, the public sector and scientific partners in the field of ocean exploration and ocean innovation is a prerequisite to maintain and strengthen the strong maritime orientation of the Netherlands.

In sectors that have a high potential for sustainable jobs and growth such as: ocean energy, seabed mining aquaculture and marine biotechnology a wide array of research themes will have to be challenged.

Outstanding research questions

The major themes in Ocean Energy are: tidal energy, wave energy, ocean thermal energy conversion, wind @ sea and floating wind farms. In these themes research is needed on the impact on the marine environment, in situ testing of innovative systems and the need for higher resolution field data and more extensive time series.

Within Bio Based Economy the important subjects are: developing and testing more selective innovative fishery methods; improving fishery management by expanding the toolset for measurements

exploration; on biodiversity hotspots, breeding grounds for fish and marine protected area's exploration and data for modelling are needed.
The major challenges in Deep Sea Mining are: understanding the impact on the marine environment; investigating the recovery of the seabed after mining operations, measuring and modelling the dispersion and the environmental impact of the sedimentation plumes; the development of new exploration tools and the in situ testing of innovative production equipment.
In deep sea and Arctic oil and gas research questions are measuring, understanding and accessing the environmental impact of operations such as trenching, in-situ testing innovative systems such as moorings and deep sea well intervention; and understanding underwater storms by measuring, modelling and predicting the impact offshore operations.
The major research themes in Ocean Pollution are: environmental improvement of European sea and the oceans, ocean plastic soup, micro plastics in the oceans, radioactive pollution, the environmentally bad state of the Baltic Sea, decommissioning of oil rigs and ocean monitoring. The major research questions are found in: measuring dispersion and the environmental impact; proposition of counter measures; the limited availability of data and lacking spatial resolution.

Collaboration
Extensive collaboration with partners from the Maritime Industry, Government, universities and research institutes is paramount.
Partners is this research will be:
Maritime industry: Royal IHC, Bluewater, Boskalis, Van Oord, Shell, Seatools, Heerema, etc, etc.
Government: Ministry of OCW, Ministry of I&M, Ministry of EZ, RWS, EU, ISA (International Seabed Authority), IMO (International Maritime Organisation),
Universities: Delft University of Technology, University of Twente, Eindhoven Technical University, Utrecht University, Wageningen University, University of Amsterdam, University of Groningen, European universities, etc.
Research institutes: TNO, IMARES, Deltares, Marin, Offshore Technology Centre (io), etc, etc.

All these institutes, companies and currently in different constellations working together using marine research facilities. NIOZ, Deltares, TNO and IMARES are, moreover, actively working in the so-called MUST consortium.

Research setup
The research in these fields requires the newest en newly to develop tools to be deployed an operated on site in the Blue Ocean. A special defined, state of the art (autonomous) toolset for marine research and access to a modern, fully equiped, ocean-going research vessel is required.

Scientists active with in this theme
Prof Dr GJ Reichart (NIOZ/Utrecht University)
Prof Dr CPD Brussaard (NIOZ/University of Amsterdam)
Prof Dr B Vermeersen (NIOZ/Delft University of Technology)
Prof Dr H Lindeboom (Wageningen University)
Prof Dr Th Baller (Delft University of Technology)
Prof Dr Ir M Kaminsky (Delft University of Technology)
Prof Dr Ir C van Rhee (Delft University of Technology)
Prof Dr A Metrikine (Delft University of Technology)
Prof Dr P Havinga (University of Twente)

Technical case

- Beschrijf welke onderdelen/technieken beproefd zijn en welke geheel of gedeeltelijk nieuw?

New technological developments are redirecting the focus of observations towards un-manned vehicles such as gliders, AUV and crawlers. Existing techniques and the further development of these techniques require intensive cooperation between technological and scientific departments within a hardware environment. Although such systems are autonomous, this equipment still requires a ship for transport to the deployment location and also for regular maintenance.

The current infrastructure and hence also the new to be built vessel need to be geared more towards using autonomous operating equipment. Such equipment will extend the abilities of the (Dutch) marine research community towards areas traditionally difficult to access and to year-round presence for physical, chemical as well as biological observations. Such an extended reach of the novel infrastructure, in combination with existing expertise, will greatly improve attraction of the facility, both for new researchers and for fostering talent present in the Netherlands.

Uitdagingen en risico's

- Beschrijf de belangrijkste technische knelpunten en geef aan hoe deze opgelost zouden kunnen worden.

No major technical challenges are foreseen for the building of the vessel as such. Technical challenges mainly rather lie in the power supply of deep-sea instrumentation and the communication between seafloor and sea surface to transfer data. Sufficient space and crane capacity is needed on a research vessel to operate AUV, ROV and deploy and maintain the observatories. In addition, pilots that can operate the ROV and AUV need to be trained.

- Beschrijf de belangrijkste risico's.

All types of marine research critically depend on using sea going capacity (vessels, vehicles, stations, and adequate marine sampling techniques and various observational equipment). From the 80's well into the new century investments have indeed been made in national marine research infrastructure (e.g., RV Pelagia), managed by NWO through Royal NIOZ. As a consequence Dutch marine research is still internationally at the forefront. Yet, the past decades have seen declining funding, while the knowledge-demand is ever growing.

In order to allow Dutch research to maintain its advanced position major investments in new infrastructure and novel techniques, leading to new and innovative science are now urgently required. Also our ability to train, retain and attract new researchers, but also international cooperation in research of all marine domains will depend on the continued, and improved availability of efficient sea-going research platforms and state-of-the-art associated facilities.

B.INBEDDING

Hoe past dit voorstel in het (internationale) landschap van grote onderzoeksfaciliteiten?

- Hoe wordt de nationale toegang gegarandeerd?

The NMF is embedded in NWO-Royal NIOZ since 2016 and is managed by a dedicated operational manager. This operational manager organizes daily operations as well as, together with the financial head of NIOZ, prepares plans, which are based on feasibility and financial consequences, evaluated by the director and management team of NIOZ. For the here requested funding for a national facility a separate evaluation board will be installed, consisting of leading persons from marine academia, research institutions, policy makers and industry, deciding on the use of the facilities **(National Marine Board, NMB)**. For this all involved stakeholders will be invited to nominate potential members. In addition, for various sectors/types of infrastructure, dedicated user-groups may be formed.
Access to the infrastructure is granted through the national or international grant schemes. Scientists working in the Netherlands who submit research proposals to the national science foundation or to the European Union and include ship time in their grant request will have automatic access to the infrastructure when their grant is funded. Access to the infrastructure includes use of the ship and crew, full board, access to all equipment in the National Marine Equipment pool and technical support to deploy the equipment. Furthermore, scientists receive all necessary support in the planning and preparation for the cruise. All other groups can get access to the infrastructure by chartering the facilities, by paying a daily rate for the ship and an agreed charter fee for equipment and support personnel.

For the here requested support a separate evaluation board will be installed (National Marine Board, NMB, see above). This board, consisting of representatives of all involved stakeholders, will oversee ship time allocation and facility use. Dedicated user-groups, for various sectors/types of infrastructure, will advice on investments and use of this infrastructure.
- Sluit het aan op reeds bestaande faciliteiten?
Marine and maritime research in the Netherlands is until 2015 catered for by the Marine Research Facility (MRF), of which *RV Pelagia* is the flagship. The here proposed new large scale infrastructure forms the replacement of the currently operated research vessel *Pelagia*, building upon existing know-how, facilities and organization structures in place. *RV Pelagia* is the only ocean-going multi-purpose research vessel under Dutch flag, operating worldwide, which can facilitate seagoing research in all marine science disciplines. In addition, MRF/NMF operates two smaller vessels (*RV Navicula* and *RV Stern*) and a wide array of marine research equipment. Traditionally research focuses on geology, geophysics and all aspects of biological research, more recently extending towards technical applications. From 2016 onward these activities will be continued in the National Marine Facilities (NMF).
- Zijn er voor zover bekend vergelijkbare ideeën (of al bestaande faciliteiten) in het buitenland? Zo ja, zou Nederland een aparte nationale faciliteit moeten hebben of betreft dit een internationale faciliteit op Europees of mondiaal niveau?
The new to develop research vessel, will be integrated in the Dutch contribution to the OFEG cooperative research effort of European maritime nations. It is our national ‘passport’ to sustain international cooperation of scientific exchange between the major European oceangoing nations, i.e. most efficient use of European marine infrastructure. In addition, through NMF, the Netherlands via Royal NIOZ participates in the global network of maritime nations through POGO, the global ocean observation program in which major players like the US, Japan, China, Russia, Australia a.o. cooperate. Being able to operate its own research vessel allows the Netherlands to participate in international research efforts as well as giving our policy makers the possibility to participate in an informed way in international marine affairs. Furthermore, our national (NWO) contribution to the ‘International Ocean Discovery Program’ (IODP) can be aligned with NMF through in kind-contributions in the future. The national research vessel will be designed in such a way that it will be suitable to carry out European ECORD mission specific expeditions in which autonomous seafloor drilling systems will be deployed, either through collaboration with German partner institutes (MARUM, MEBO-system) of through partnership with Dutch industry (IHC, SWORD-system).
Hoe past het voorstel bij de NL sterktes van onderzoek?
See above
Beschrijf de voordelen/belang voor NL indien zo’n faciliteit zou worden gerealiseerd. Dit mogen zowel wetenschappelijke als economische of maatschappelijke voordelen zijn.
The users of the NMF will be coming from the Dutch marine and maritime research community in general. Whereas more recently increased interest for the usage of sea going facilities comes from industry, the more traditional marine sciences remain the main anticipated user group. This encompasses Marine biology in its’ broadest sense, Geology, Environmental Chemistry, Physical Oceanography, Physical Geography, Archeology and Marine Technology. This community is relatively small, but internationally at the fore front of (marine) sciences and fully relies on the NMF for all sea

going activities. Also internationally the NMF is an important component of the marine research sea scape and involved in multi-national research consortia. This participation is, however, always financially setup in such a way that revenues flow back into NMF. Still, this participation plays an important role in the international proliferation of the Dutch Marine Sciences.

From a valorization point of view, the Dutch Marine Industry would greatly benefit from the here proposed new facilities as new techniques can be tested, certified and marketed. For example, a new to develop vessel and techniques integrated will allow the Dutch Industry to use the vessel during international missions as testing platform and international showcase. Also Dutch commerce would benefit from such a vessel as mess rooms and laboratories potentially provide a high profile outlet to be used at international business missions. Besides industry, also the more applied national research institutions like TNO, Deltares, IMARES and such have increasing needs for sea-going facilities (building with nature). Integrated use of the new research vessel will therefore propel new research, valorization and policy making.

The new to build research vessel will be a vital national instrument to unite Dutch marine and maritime research efforts, combining various economic topsectors, academia, research institutes and ministries. It will allow an efficient implementation (cf. the recent AWT-advice '*Maatwerk in onderzoeksinfrastructuur*') of public investment in large national research facilities from a clear national strategic vision on the academic, valorization and societal needs of The Netherlands in the long term. A proven track record of valorization projects in which the marine facilities were pivotal exists and will form the basis for the future expansion of such activities.

C. ORGANISATIE

Organisatie

Geef aan welke partijen/expertise nodig zijn voor de ontwikkeling van deze faciliteit. Geef ook aan of en zo ja hoe deze al zijn betrokken.

NIOZ/NMF is in direct contact with the various national marine technological research institutions such as MARIN and TNO, besides multiple national offshore industries such as IHC Merwede, van Oord, Allseas and the like, notably via the MKC and Topsector Water platforms, (topsector maritime) – to allow for the required technological design and construction issues. These parties have been extensively involved, both directly, as well as via a recent national electronic query, and are, and will be, providing input.

Along other lines, discussions are ongoing concerning participation of 'Rijkswaterstaat' (I&M-RWS) and the 'Rijksrederij' (RWS-RR) to discuss options (investment, exploitation, partnership), besides intensive contacts on NWO/OCW levels and other relevant ministries (EZ, BuZa, I&M).

Exploitation and development: Royal NIOZ has a long standing history for successful exploitation, operation and development of such an enterprise. Sea above for the proposed setup of the scientific committees associated with this project.

Beschrijf de (mogelijke) organisatiestructuur. Geef ook aan of er al een begin van organisatievorming is.

RV *Pelagia* was built in 1991, financed through a special grant from the ministry of OC&W. In 1995 ownership was transferred from NWO to NIOZ and from that moment onwards NIOZ has been responsible for all costs associated with maintaining and running the infrastructure. Until 2009 access to the infrastructure was granted through special calls for seagoing research and budget for those ALW granted research cruises was approved by the ALW board and transferred to NIOZ.

Separate funds were available for the marine equipment pool, with the ALW board approving the capital investment plan annually. Since 2012, ALW no longer approves cruise budgets and investment plans but pays a lump sum to NIOZ for use of infrastructure by university scientists. Access to the facility is currently organized through the NIOZ director and management team, based on internal and external proposals via MRF staff. Within the new NMF structure a separate board **(National Marine Board, NMB)** will overseeing ship time allocation and facility use.

D. VERDERE ONTWIKKELING

Beschrijf wat er moet gebeuren om deze faciliteit verder te ontwikkelen. Ga in op de belangrijkste knelpunten die opgelost moeten worden.

The now required decision-making critically hinges on the national willingness to acquire, build, exploit and operate a national ocean going research platform.

Geef aan wat de ontwikkeltermijn voor deze faciliteit ongeveer zou kunnen zijn.
Based on the remaining life time of RV *Pelagia* a new to be built ship should be ready in 2022. The first design phase ideally would start 4 years earlier, in 2018.