WP1 Physical Processes in the Upwelling System

SEASONAL VARIABILITY: What defines the timing of upwelling?
What happens in non-upwelling periods and during the transition periods?

EXCHANGE PROCESSES: Which physical processes drive nutrient fluxes in the water column, across the air-sea and sediment-sea boundaries and between near-coastal and open ocean?

PHYSICAL-BIOLOGICAL COUPLING: What are the coupled physical-biological processes relevant for nutrient and carbon budgets, productivity, and ecosystem dynamics?

CLIMATE: What are the physical mechanisms of upwelling-induced ocean-atmosphere interaction and feedback linking the Eastern Boundary Upwelling System with large scale climate variability?

FUTURE: How does the physical forcing of upwelling and the physical-biological coupling change under global warming, and which processes are affected?

WP2 Biogeochemical Cycles under Climate Change

SEASONAL AND SPATIAL PATTERNS : How do biogeochemical processes and their potential driving factors (e.g. nutrient or dust supply, wind driven mixing) vary with time, space and oceanic features?

CLIMATE AND ANTHROPOGENIC INTERACTIONS: How do biogeochemical processes respond to climate stress and human-induced changes to the ocean? How do the changes influence carbon sinks and sources in open ocean and coastal habitats?

BIOGEOCHEMICAL PROCESSES: How are biogeochemical cycles coupled to physical processes and how do changes in them impact biodiversity and ecosystem functioning?

FUTURE AND KNOWLEDGE TRANSFER: How can spatial and temporal patterns be implemented into climate models to predict future change in Eastern Boundary Upwelling Systems and inform coastal protection options?

WP3 Biodiversity and Ecosystem Functioning

SEASONAL VARIABILITY: How do the phytoplankton communities responsible for primary production vary across seasons and how is this impacting the microbial food web and the grazer food web?

SPATIAL PATTERNS – VERTICAL STRUCTURE AND SHELF-TO-OPEN-OCEAN TRANSITION: How are food webs linked throughout the water column and how is this vertical connectivity modulated by physical factors?

TROPHIC TRANSFER UP TO FISH: What are the physical and ecological key factors that determine the efficiency of trophic transfer from plankton and microbes to fish and megafauna in the Eastern Boundary Upwelling Systems?

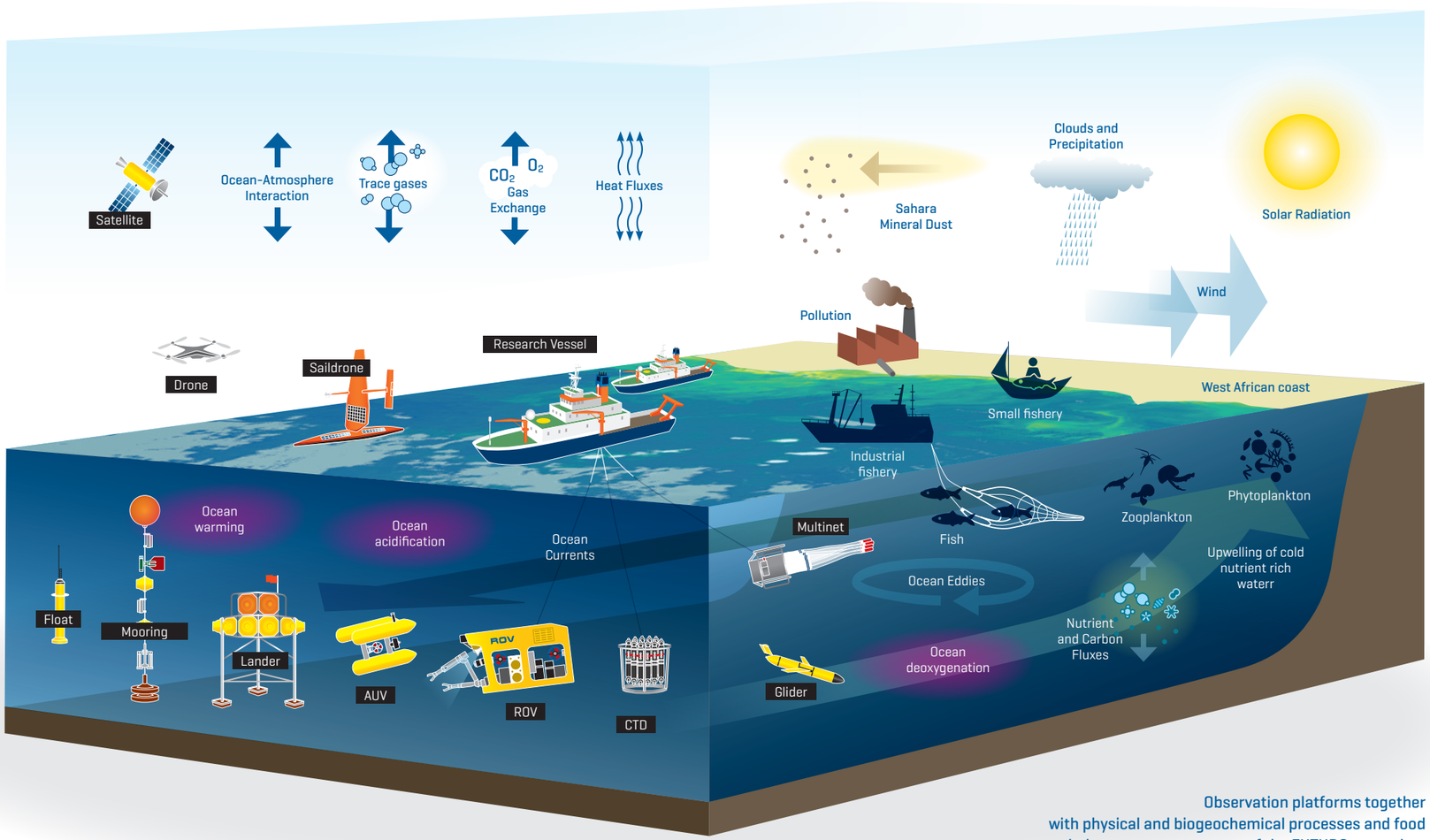
FUTURE & PREDICTABILITY: How does climate change impact ecosystem productivity and trophic transfer? What is their sensitivity and how can our work help to inform models?

Societal Relevance, Participatory Management, and Knowledge Co-production

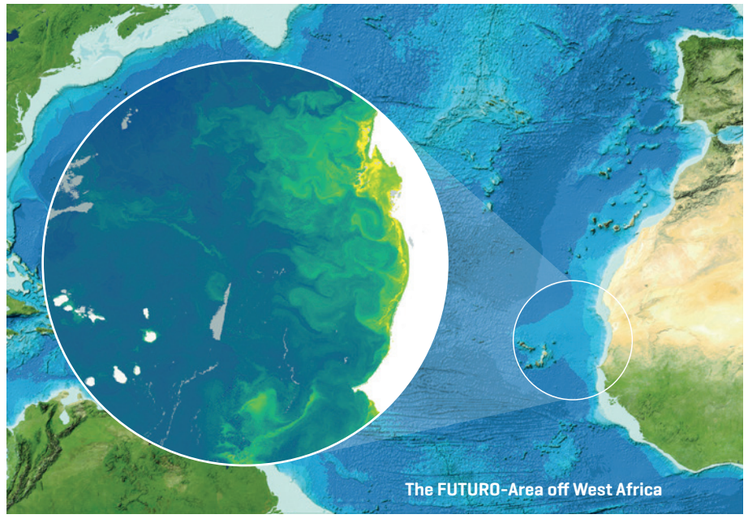
Crucial socio-cultural and politico-economic research questions:

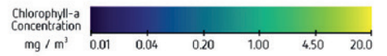
- **What are social/economic concerns and perceived environmental issues for small-scale fishers and other local stakeholders?**
- **How can different stakeholder's perspectives be integrated in a natural resource management context?**
- **What type and intensity of sustainable use of upwelling areas will be possible in the future?**
- **How will coastal upwelling changes in the future affect different interest groups and redistribute resource use benefits?**
- **To what extent will current governance and (local) management approaches have to be adapted?**
- **How can cooperation among coastal countries, regional organisations and the international science community be improved and what transformative forms of knowledge-based governance are conceivable?**
- **Which responsibilities do countries like Germany and the EU have in this context?**

There is an urgent need to generate the necessary socio-cultural and politico-economic knowledge and to transfer it into application together with the responsible actors. Knowledge-based, sustainable and fair management must also meet ethical, cultural and economic requirements and develop suitable political and economic steering instruments at various levels. The process of knowledge production must therefore be developed from the outset in co-creation with stakeholders and the users of knowledge in an inter- and transnational context.



Observation platforms together with physical and biogeochemical processes and food chain components as part of the FUTURO campaign.





The satellite image shows the concentration of chlorophyll in the ocean, which is an indicator for phytoplankton biomass. ©EUMETSAT 2022, Background map: GEBCO

FUTURO is based on the following values and practices:

- **Active partnership with West African researchers, stakeholders and marine research institutes:** West African experts will be essential partners in the co-design. They are invited to become partners of the FUTURO experiment.
- **Involvement of all interested parties in the German research landscape:** The experiment is a major joint project initiated by leading national research institutes in Germany.
- **Coordination with international research communities:** The experiment is to be widely presented and promoted internationally. Scientific co-operations are explicitly desired.

The significance of the Eastern Boundary Upwelling System (EBUS)

Eastern boundary upwelling systems are among the most biologically productive and biodiverse regions of the world ocean and are thus of highest ecological and socio-economic importance. They are an integral part of the climate and subject to strong human-induced influences.

In upwelling regions, ocean warming, ocean acidification and ocean deoxygenation act together and can lead to possibly synergistic effects that can have negative consequences on ecosystem functioning. High fishing pressure, coupled with often inefficient fisheries management, unsustainable economic incentives and land-based pollution also have the potential to further worsen the situation. We have reason to believe that the functionality of coastal upwelling areas is particularly sensitive to these factors, for which reliable future scenarios are lacking. Significant changes in the ecosystem services that are extremely important for humankind are therefore to be expected.

The pelagic system of the major eastern boundary upwelling systems is characterised by a multitude of dynamic processes and a complex coupling of physical, chemical and biological factors. While an in-depth and system-wide description is missing so far, it is absolutely essential to develop reliable scenarios and forecasts of future changes. Such a thorough 'description' can only be achieved through a multidisciplinary approach given the complexity of the ecosystem, as well as the external and internal interactions and feedbacks, and the broad spectrum of relevant spatial and temporal scales, all of which require an innovative and holistic research perspective. With its advanced tools, the international marine research community has all the prerequisites to successfully address these extremely important in many respects.

FUTURO – An all-season multiscale research campaign on the future evolution of the coastal upwelling system off West Africa

An adequate scientific characterisation of coastal upwelling systems requires a methodological approach that corresponds to the complexity of the external and internal couplings and the scales of the spatiotemporal variability of the physical-chemical-biological-geological system and at the same time takes the socio-scientific context into account in a holistic way.

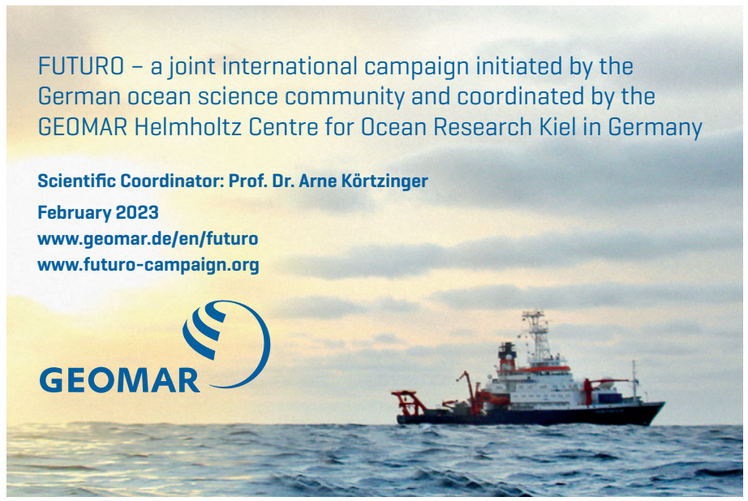
As a major step towards this, the yearlong large-scale observational campaign FUTURO has been proposed and is planned for the time frame 2026-2027. One or more research vessels are expected to operate throughout the campaign in the larger West African EBUS region executing a sequence of coordinated and concerted multidisciplinary surveys and experiments supplemented by a large number of autonomous and voluntary observing instruments and regional research capabilities.

The combination of field work, remote sensing from space and planes as well as near real time modelling will provide an unprecedented data set and new insights. The scientific ambition as well as the exchange of new knowledge with regional partners will be co-designed with experts from the West African region. Several working groups have been stepped up to articulate the scope of FUTURO. The socio-anthropological perspective will be an integral part of each of these thematic parts.

Physical Processes

Biogeo-chemical Cycles

Biodiversity and Ecosystem Functioning



Interested in joining FUTURO?
Please contact: info@futuro-campaign.org