Rundgespräch on the topic of

Future of Tropical Upwelling Regions in the Atlantic Ocean (FUTURO)

A multi-scale, year-round, multidisciplinary observational campaign in the tropical North Atlantic upwelling system off West Africa

Topic and relevance of coastal upwelling systems in the Anthropocene

The large coastal upwelling systems (Canary, Benguela, California and Humboldt Currents) are among the most biologically productive, biodiverse and fisheries-important regions of the world ocean, and are thus also of highest socio-economic importance. They are physically driven by trade winds and are characterised by an intensive interaction between the atmosphere and the ocean, which makes them climate-sensitive as well as climate-effective. The pelagic system of upwelling areas is characterised by a multitude of dynamic processes and a multi-layered coupling of physical, chemical and biological factors. A deep and system-wide description, which needs to be developed in a multi- and transdisciplinary approach in order to develop reliable scenarios and forecasts of future changes, is missing so far. An important reason for this is the complexity of the entire system, the external and internal interactions and feedbacks, as well as the broad spectrum of relevant spatial and temporal scales, which can only be captured by an innovative and holistic research approach. German marine research has all the prerequisites to successfully address these questions of the future, which are extremely important in many respects.

Coastal upwelling areas are subject to several strong anthropogenic influences. Ocean warming, ocean acidification and oxygen depletion come together and can lead to synergistic effects. High fishing pressure, coupled with often inefficient fisheries management, unsustainable economic incentives and land-based pollution are other direct human impacts. It is feared 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 to be expected.

FUTURO
A multi-scale experiment in the coastal upwelling system off West Africa

An adequate scientific description 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. With the one-year large-scale experiment FUTURO (Future of Tropical Upwelling Regions in the Atlantic Ocean) planned for the time frame 2025-2027, a decisive scientific progress in coastal upwelling off West Africa (Canary Current System) is to be achieved here. The basic concept of FUTURO is based on the following aspects:

- Involvement of all interested parties in the German research landscape. The experiment is a major joint national project.
- Coordination with contributions from the international research community. The experiment is to be widely presented and promoted internationally. Scientific contributions are explicitly desired and will be coordinated as part of the overall concept.
- The experiment is to run for a full year cycle. Autonomous and ship-based observations are to take place continuously as far as possible during this period. The continuous presence of a German research vessel is desired. Targeted process studies and intensive campaigns will be integrated into the ongoing activities.
- The observation concept of the classical oceanography is expanded to include the new possibilities of autonomous observation technologies (autonomous surface and

underwater vehicles, robotics, etc.) and innovative sensor technology. The concerted and interactive use of a large number of autonomous platforms, which has hardly been realised in this form, is carried out in combination with innovative experimental approaches and with the integration of up-to-date information from remote sensing.

- FUTURO will be supported and guided by high-resolution modelling for the preparation, implementation and evaluation of the large-scale experiment.
- Innovative concepts such as Citizen Science, Digital Twins, decision arenas, visualisation of future states, etc. are conceivable.
- A broad multi- and transdisciplinary approach with early involvement of the social sciences is sought.

Nothing like this has been done before, and the experiment will provide a valuable reference data set as a basis for a fundamental understanding of the system. However, FUTURO can only be successful if it is designed from the perspective of the societal questions of sustainable use that need to be answered and if it is integrated into specific socio-scientific accompanying research.

Social relevance and knowledge transfer

Crucial questions are being posed to research from society: How will coastal upwelling areas change in the future? How can we move towards a path of sustainable use? What kind and intensity of use of upwelling areas is possible in the longer term? How can cooperation with coastal countries and regional organisations be improved and what transformative forms of governance and rules are conceivable? What responsibilities do countries like Germany and the EU have in these processes? Therefore, there is an urgent need to generate the necessary knowledge for action and to transfer it into application together with the responsible actors. Knowledge-based, sustainable and fair management must also meet ethical, economic and cultural requirements and develop suitable legal and economic steering instruments at various levels. The process of knowledge production must therefore be developed from the outset in co-creation with social interest groups and the buyers of knowledge in an international context. The research and its results should be presented to the general public with the help of multimedia science communication.

National and international visibility and networking

The idea of the FUTURO mission is already supported by a broad spectrum of institutions and actors in Germany and would also arouse great international interest and certainly be expanded to include important contributions from the international research community. At the same time, it meets with considerable expertise in the German science system in the field of large coastal upwelling areas. For example, the BMBF is currently funding three research networks in coastal upwelling areas (CUSCO, EVAR, REEBUS).

In the planned FUTURO mission, German marine and earth system research can demonstrate its extensive experience and strong infrastructure. By integrating expertise from the humanities, economics and social sciences, we can also expect closer links between universities and research institutions across the boundaries of natural science research.

Coastal upwelling regions are also focus of international marine research and have been identified as main topics in several major international programmes such as CLIVAR (Climate and Ocean - Variability, Predictability and Change), SOLAS-int (Surface Ocean – Lower Atmosphere Study) and IMBeR (Integrated Marine Biosphere Research). Regional fisheries programmes (ICES, PICES, RMFOs etc.) and UNEP 'Regional Seas' also have activities in upwelling regions with which networking should be aimed. The proposed FUTURO mission follows the goals of the "UN Decade of Ocean Research for Sustainable Development (2021-2030)".

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