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Review

Climate change and anthropogenic impacts on marine ecosystems and countermeasures in China

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Abstract

The ecosystems of China seas and coasts are undergoing rapid changes under the strong influences of both global climate change and anthropogenic activities. To understand the scope of these changes and the mechanisms behind them is of paramount importance for the sustainable development of China, and for the establishment of national policies on environment protection and climate change mitigation. Here we provide a brief review of the impacts of global climate change and human activities on the oceans in general, and on the ecosystems of China seas and coasts in particular. More importantly, we discuss the challenges we are facing and propose several research foci for China seas/coasts ecosystem studies, including long-term time series observations on multiple scales, facilities for simulation study, blue carbon, coastal ecological security, prediction of ecosystem evolution and ecosystem-based management. We also establish a link to the Future Earth program from the perspectives of two newly formed national alliances, the China Future Ocean Alliance and the Pan-China Ocean Carbon Alliance.

Keywords: Global climate change; Anthropogenic activities; Blue carbon; Coastal ecological security; Ecosystem evolution; Ecosystem-based management

1. Introduction

Since the industrial revolution, the atmospheric CO_2 levels have increased from approximately 280×10^{-6} to more than380 $\times 10^{-6}$ (IPCC, 2013), which is the highest in the history of the Earth for the past 800,000 years (Lüthi et al., 2008). This increase rate is believed to be faster than that happened over millions of years (Doney and Schimel, 2007). With the warming effects of CO_2, an increase of air temperature of 2.6—4.8 °C by the end of the 21st century is projected under the condition of Representative Concentration Pathways 8.5 (RCP 8.5) (IPCC, 2013). The oceans, covering more than 70% of the Earth's surface, include coastal, continental margin, open ocean, and sea-ice covered systems. The oceans play an important role in regulating climate by storing and redistributing materials, energy and heat. For example, the oceans act as the major sink for CO_2 (Le Quéré et al., 2014). Since the beginning of the 19th century, the oceans are estimated to have taken up about 50% of fossil fuel emissions and about 30% of

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anthropogenic emissions, thus significantly reducing the accumulation of atmospheric CO_2. Meanwhile, the oceans are experiencing significant variations on different space and time scales as a result of climate change, which in turn affect the human communities that rely on oceanic services and resources.

The physical and chemical features of the oceans have changed with the increased transferring of CO_2 and heat from the atmosphere (IPCC, 2013). Since the majority of the atmospheric heating induced by the increased CO_2 and other greenhouse gases was absorbed by the oceans, significant warming of the upper ocean has been reported in long-term monitoring studies. Heating of the upper ocean has led to a strong thermal stratification, and contributes to the observed global sea level rise (SLR) (IPCC, 2013). Higher sea temperatures have the potential to produce more intense storms, and the surface wind changes have changed the wave height and ocean upwelling. Increasing concentrations of atmospheric CO_2 has also influenced the chemistry of ocean waters, leading to a growing inventory of inorganic carbon. Ocean pH has declined by approximately 0.1 pH units as a result of ocean acidification (IPCC, 2013). Seawaters of low O_2 concentrations are expanding due to a number of local (i.e. eutrophication) or global drivers (i.e. increasing temperature, reduced water column mixing and ventilation).

Similarly, anthropogenic activities can produce a number of stressors (e.g. pollution, habitat fragmentation or destruction, introduction of invasive species, unsustainable fishing, hydroclimatic changes) from both land and sea that have varying impacts on different components of the marine ecosystems (Boldt et al., 2014; Rombouts et al., 2013; UNEP, 2010). There is a high risk of biological extinction and loss of vital habitats. One recent estimate found that at least 40% of the global oceans are heavily affected by human activities (IOC/UNESCO et al., 2011). Many of these effects can act additively, synergistically, or antagonistically (Korpinen et al., 2012; Rombouts et al., 2013). These changes are impairing the ocean's capacity to provide food, protect livelihoods, maintain clean water, and recover from environmental stresses like severe storms. The resilience of marine ecosystems to anthropogenic pressures is weaker than previously thought. These trends are exacerbated by the growing human populations in coastal areas and increasing need for marine resources (Claudet and Fraschetti, 2010; Rombouts et al., 2013).

China has a territorial sea area of about 380,000 km^2, and a jurisdictional sea area of 3,000,000 km^2 (Yang, 2006). The total length of its coastline is 32,000 km, with 18,000 km along mainland. China has about 7 million hm^2 of various coastal wetlands, and about 6900 islands (TLSC, 2010). Typical marine ecosystems, such as estuary, bay, lagoon, island, mangrove, coral reef, sea grass bed, etc., all exist in the China seas and coastal areas. The abundant marine natural resources and huge ecosystem service in China are important foundation and safeguard for national economic and social development. Since the 11th Five-Year Plan, China's marine economy growth rate has been higher than the national economic growth rate over the same period. The total marine production has been more than 5 trillion since 2012, which has become a new engine to drive the economic development (SOAC, 2012). However, in recent decades, China's marine and coastal ecosystems are facing a series of challenges due to the high intensity of human activity and climate change. Our artificial shoreline accounts for up to 80% of natural shoreline. The development and production activities (reclamation, oil and gas, aquaculture, shipping, etc.), as well as a sharp increase in the discharge of terrigenous nitrogen and phosphorus, organic matter, and various types of pollutants, resulted in offshore ecological disasters (eutrophication, red tide, existence and enlargement of anoxic zone) and huge economic loss. This would seriously endanger the marine ecosystem and the sustainable development of society (TRGEEP, 2010).

2. Impacts of global climate change on China seas/coasts

There are evidences that sea surface temperatures in the China seas increased in the last several decades. Since the 1980s, the Bohai Sea, Yellow Sea, and East China Sea have witnessed significant increase in sea surface temperatures (Cai et al., 2011; Lin et al., 2005, 2001). The strongest warming was observed in the East China Sea in winter (1.96 °C) from 1955 to 2005 and in the Yellow Sea in summer (1.10 °C) from 1971 to 2006 (Cai et al., 2011). The upper layer of the South China Sea warmed steadily from 1945 to 1999 (Li et al., 2002; Liu et al., 2007) and the annual mean sea surface temperatures in the central South China Sea has increased by 0.92 °C from 1950 to 2006 (Cai et al., 2008). Such a change has led to spatially non-homogeneous sea level variations (Li et al., 2002; Cheng and Qi, 2007). The projected SLR rate near China is 3.1−11.5 mm per year by 2050, higher than the global SLR rate (3.2−8.0 mm per year) (Cai et al., 2008; Yang and Sill, 1999). This implies that a total area of $(14.3-21.2) \times 10^4$ per year hm^2 might be flooded over the main coastal plain of China, which account for 2.47%−3.66% of the total coastal wetlands (Sun et al., 2015). The concentration of dissolved oxygen decreased obviously in the Yellow Sea and East China Sea (Lin et al., 2005), and the size of hypoxia areas expended in the coastal areas of the Yellow Sea/East China Sea (Tang, 2009). Severe ocean acidification has been found in the coastal water of the Bohai Sea and the Yellow Sea, and the aragonite saturation state was detected to be lower than 2 in the bottom water of most coastal zones. In particular, the autumn aragonite saturation state of the bottom water in the central Yellow Sea was down to 1, which reached the critical value for shell and skeleton dissolution (Zhai et al., 2014; He et al., 2014).

Obvious changes in biological abundance and distributions in China marine ecosystems were observed. There has been an increasing proportion of warm water species relative to temperate species from plankton to fish in the past decades in the Yangtze estuary of the East China Sea and in the south Taiwan Strait (Li et al., 2009; Lin et al., 2011; Ma et al., 2009; Zhang et al., 2005). Changes of dominant fishery species driven by multi-decadal climate variability have been reported

(Gong et al., 2007; Tang et al., 2003). Warming induced shift of the dominant fisheries occurred in the East China Sea from the 1960s to the 1980s (Chen and Shen, 1999). The northward expansion of warm-water zooplankton species were observed in the Yangtze estuary (Gao and Xu, 2011; Kang et al., 2012; Ma et al., 2009). In addition, the degradation of coral reefs and mangroves were related to the warming in the South China Sea (ECSCNARCC, 2011). It has been found that 80% of living coral cover has decreased in the South China Sea in the past decades (Yu et al., 2012). The frequency of harmful algal blooms (HAB) in the East China Sea showed an inter-decadal trend in the past decades (Ye and Huang, 2002; Tang, 2009). The SLR in the coastal zone can induce the aggravation of inshore disasters and the enhancement of coastal erosion, which significantly affect the stabilization of coastal wetlands (Yang and Sill, 1999; He et al., 2012). The result of SPRC (Source Pathway Receptor Consequence) modeling showed that the percentage of coastal wetlands within the grade of high vulnerability increased significantly in the Yangtze estuary (Cui et al., 2015). The evaluation by using Sea Level Affecting Marshes Model for the Tieshangang Bay showed that 18.2% and 25.2% loss of mangrove habitats would be inevitable in 2100 in the scenarios of either the present trend (2.9 mm per year) or RCP4.5 (0.53 m SLR by 2100) (Li et al., 2015). The SLR would also increase the intensity of saltwater intrusion in coastal freshwater aquifers, consequently threatening freshwater supplies in the coastal zone. A model of ECOM-si was used to assess the influences of SLR on salt transport processes and estuarine circulation patterns in the Yangtze estuary, indicating that the intensity of saltwater intrusion and stratification both increase as a result of SLR (Qiu and Zhu, 2013).

3. Impacts of anthropogenic pressures on China seas/coasts

Humans have been the primary drivers of the changes in coastal aquifers, lagoons, estuaries, deltas, and wetlands, and are expected to further exacerbate pressures on coastal ecosystems through excess nutrient input, chemical pollution, changes in runoff, reduced sediment delivery, and land reclamation.

Marine eutrophication caused by excess nutrient input in the coastal zones became more and more severe. The annual red tide bloom events increased from 10 in the 1980s to 20 in the 1990s, and it rose to 78 in the first decade of the 21st century, nearly four times of the 1990s. In 2003, the red tide bloom events in marine environment reached 119, the highest occurrence in history (Gao and Xu, 2011). Green tide (Enteromorpha algaes) blooms also occurred frequently in the 2000s with an increased loading of pollutants in some coastal areas. In the case of Qingdao coast, the first bloom of enteromorpha algaes caused a loss of 2 billion in 2008. In addition to the increased input of nutrients to the estuarial and coastal waters, changes in land use and damming have resulted in changes in the balance among nitrogen, phosphorus and silicon elements, thus increasing the risk of algal bloom (Chen and Hong, 2012). HABs have been observed to cause adverse effects to a wide variety of aquatic organisms. It has been found that shellfish poisoning toxins and diarrhetic shellfish poisoning distributed widely in China's coastal seas due to the high frequency of HAB events. The HAB toxin can exert harmful influences on marine wildlife by changing their developmental, immunological, neurological, or reproductive capacities, as well as impact human health by accumulation in marine food products (Lan et al., 2013).

Hypoxia is formed in the bottom waters of estuaries and coastal continental shelves as a result of enhanced production of organic matter. The hypoxia area off the Yangtze estuary has increased sharply from 1800 km^2 in 1959 to 15,400 km^2 in 2006, caused mainly by the dramatic increase of nutrient supply by the river (Zhou et al., 2009). However, the degrees of hypoxia vary for different regions of China seas/coasts; they are strongest overall in the north and near-shore areas, and weakest on the outer continental shelf (Wei et al., 2015).

Chemical pollution is one of the major challenges to the sustainability of coastal ecosystems. It was reported that the pollution sources mainly came from the land affected by agricultural or industrial activities and livestock or domestic waste discharge, and also from coastal waters by aquiculture and other anthropogenic activities. According to the statistical data provided by the Ocean Environmental Quality Bulletin of China during 2003–2014, the major pollutants (COD, nutrients, petroleum, heavy metals and arsenic) in the Yangtze estuary and Pearl River estuary were generally higher than these in other estuaries. In addition to the above mentioned pollutants, emerging contaminations such as PFOA, PBDEs, PCNs, antibiotics were also observed ubiquitously along the east coast of China (Wang et al., 2015; Zhang et al., 2013). Bioaccumulation of the toxic pollutants in algae and bivalve shellfish might cause potential human health risk by consumption of marine food products (Chen et al., 2014). Oil spill is another kind of anthropogenic pollution occurred at the oil jetty, port, oil pipeline distributed in the coastal area and offshore drilling platform. According to statistical records, there was an average of two oil spill accidents per year in China seas from 1973 to 2006, with an annual spill amount of 537 t. More seriously, occurrences of extremely serious oil spill accidents increased sharply in the last several years. In 2010, two extreme oil spill accidents occurred in the Bohai Sea, which have severe and long-lasting effects on the marine and coastal ecosystems (Liu et al., 2011).

Over nearly 70 years, especially in the period of 1990–2000, the degree of coastline utilization in mainland China had a continuous and significant increase, with the portion of natural coastline decreased to 40% (Wu et al., 2014). Most of the tidal flat and wetland were transformed to port, industrial park and aquiculture base by reclamation, and the reclaimed area had amounted to 12,000 km^2 by the end of the 20th century. For the last two decades, the reclamation in China expanded dramatically at a speed many times faster than before, especially in Bohai Bay. Reclamation caused a huge loss of coastal wetland and habitats, with approximately 3.86×10^6 hm^2 coastal wetland being reclaimed or greatly destroyed during 1991–2014 (Sun et al., 2015).

Excessive fishing in the coastal zones during the past several decades has induced severe degradation of inshore fishery resources. It was reported that the inshore fishing increased from 2.8×10^6 t to 11.5×10^6 t during 1980–1996, with an increasing rate of 310%. The inshore fishing significantly exceeded the annual permitted value (8.0×10^6 t) after 1994 and stayed high afterward. By 2012, the inshore fishing amount reached 12.7×10^6 t due to greatly increased fishing vessels and vessel power (Lu, 2005; FBCMA, 2013), but the catch has dramatically shifted from large high-valued species to small low-valued ones.

4. Challenges and future research foci of China seas/coasts ecosystem studies

The complexity of the China seas/coasts ecosystem, in terms of its physical, chemical and biological interactions with the land and ocean, requires systematic and integrated scientific research to understand its responses to climate change and anthropogenic activities, and its impacts on China society. Although considerable progress has been made during the last few decades, the studies of this complicated ecosystem are facing several challenges. In particular, due to historical reasons, there is an apparent lack of national strategy, long-term mission and large scale research facilities. Here we list several urgent needs for policymakers.

4.1. Long-term time series observations of the whole ecosystem at multiple scales

Long-term time series marine observations played an important role in our understanding of climate change and ecological processes, and in our development of physical-biogeochemical-ecological coupled ocean models (Ducklow et al., 2009). There are some well-established marine time series such as the Bermuda Atlantic Time-series Study (BATS) and the Hawaii Ocean Time-series (HOTS) stations in the Atlantic and Pacific Oceans, respectively, which have provided a large volume of marine ecology and biogeochemistry data (Ducklow et al., 2009). Although there are routine marine monitoring stations in China such as those maintained by the State Ocean Administration (SOA), they only measure very basic ocean parameters and are limited in spatial coverage. For a better understanding of the changing climate and ecosystem, fundamentally new and science-driven long-term time series observations of the whole ecosystem at multiple scales are needed for China seas/coasts. A pilot program was established recently under the Pan-China Ocean Carbon Alliance. A number of marine observation stations were set up in the Bohai Sea, East China Sea, and South China Sea. Different to those developed and organized by State Ocean Administration, these stations have clear scientific objectives (ocean carbon), have well-designed process and experimental components, and cover a large range of ecological, biogeochemical, physiological, trophic, spatial, and temporal scales. This might serve as a model for modern marine observatory stations in China.

In the long run, there is a clear need to strengthen the long-term simultaneous monitoring capabilities for climate, hydrology, pollutants, ecosystem, disaster etc., in the coastal zones of China, to establish a systematic observation network covering watershed, estuary, wetland and offshore regions, to develop advanced monitoring and observation techniques based on satellite remote sensing, radar, sonar, biological and material technologies, and to form a systematic information system that integrates automatic data transmission with data management and analysis for improvement of data sharing.

4.2. Meso- and macro-scale facilities for simulation study

Due to the vast span of temporal and spatial variability of the ocean environment, present investigations based on either research vessels or offshore-based monitoring stations are limited in many aspects. Some of the long-term experiments designed with specific scientific goals are difficult to implement in the real ocean. In particular, the need of linking global climate change to marine ecosystems cannot be met to its full extent with *in-situ* data. Therefore, large scale experimental facilities that provide a platform to simulate meso-scale ocean environment is of vital scientific and practical significance. A common tool used for ecosystem simulations and experiments is the mesocosm. The preponderance of mesocosm experimental setups is the ability to imitate natural conditions, which have already greatly contributed to our knowledge of the processes and mechanisms of ecological systems. However, mesocosm has limited ability to control environmental conditions and has difficulty to simulate environmental changes such as temperature increase. Therefore, a fully controlled meso- or maco-scale experimental facility is necessary for the studies of China seas/coasts ecosystem. Here we introduce such a facility, Marine Environmental Chamber Systems (MECS).

The core part of the MECS constitutes of 4–6 large chambers/capsules, each is 30–50 m in height and 3–5 m in diameter. They are equipped with a step-by-step monitor system on marine environment conditions, including temperature, light intensity, pH value and CO_2, dissolved oxygen and nutrient level; they also have automatic sampling, sample pretreatment, distribution, integrated data analysis and system management functions, as well as high precision automatic control. The minimum goal of building the MECS is, through a combined manipulation on all relevant parameters, to conduct long-term biological incubation experiments and to study various ocean biogeochemical mechanisms and processes (e.g. ocean carbon sink and long-term change of dissolved organic carbon). The proposed MECS generally comprises of 12 operational modules, i.e. sea water culture system, temperature control system, lighting system, ventilation system, charging system, mixing system, filtration system, sample collection system, on-line monitoring system for environmental parameters, on-line monitoring system for biological parameters, database system and control system.

4.3. Blue carbon

Out of all the carbon captured in the world by living organisms and ecosystems (called green carbon), over half (55%) is captured in the oceans (called blue carbon). Compared to green carbon which is well studied, our understanding of the mechanisms and processes of blue carbon is quite limited and the protocol for quantification and sequestration of blue carbon has not been established yet.

The long-term *in-situ* monitoring and laboratory simulations of wetland carbon flux should be strengthened to explore the role of coastal carbon cycle in the global carbon cycle, and to determine the status of coastal wetlands as carbon source or carbon sink. New technologies like Remote Sensing (RS) and Geographic Information System (GIS) should be used to establish long-term coastal monitoring platform to study the response and feedback of China's coastal wetland carbon stock to global climate change. This would be helpful for climate and environment related policymaking.

The well-known biological mechanisms for blue carbon sequestration in the ocean is the biological pump (BP), which is driven by primary production in the euphotic zone and then mediated by the sinking process of particulate organic carbon (POC) in the water column. However, the carbon captured by living organisms in the oceans is stored not only in the form of sediments from mangroves, salt marshes and seagrasses, but also in the form of dissolved organic carbon (DOC) in the water column. The DOC pool is huge and accounts for more than 90% of the total marine organic carbon. The majority of marine DOC is recalcitrant, which has an average residence time of ~5000 years and thus plays an important role in the sequestration of carbon in the ocean. A recently proposed concept, the microbial carbon pump (MCP) (Jiao et al., 2010) offers a formalized and mechanistic focus on the significance of microbial processes in carbon storage in the recalcitrant DOC (RDOC) reservoir. Therefore, further development of blue carbon research must include both BP and MCP.

Recently, Chinese scientists proposed an integrated project called China Blue Carbon Project. The major missions of this project are to: 1) investigate the mechanisms and processes (e.g. BP and MCP) of blue carbon in China seas/coasts; 2) estimate the flux and sequestration of blue carbon in China seas/coasts; 3) develop blue carbon sequestration techniques via sea-land coordination; and 4) standardize the protocols for quantification and management of blue carbon sequestration. The implementation of China Blue Carbon Project will contribute to our understanding of global carbon cycling and to the national 21st century maritime Silk Road strategy of China.

4.4. Coastal ecological security

The exacerbation of anthropogenic activities and global climate change has resulted in an increasingly severe ecological security problem in the marine ecosystems in China. Coastal ecological security has become a national strategic issue, an important part of national security, and the core of sustainable marine development (Yang et al., 2011). Accordingly, a series of research priorities are identified to safeguard the coastal ecological security in China. First, the vulnerability and health of typical ecosystems like estuary, coral reefs, seagrass beds, mangrove, etc., should be systematically evaluated, with the degradation mechanism of these ecosystems being studies. Second, we need to explore the offshore eutrophication process and the ecosystem response, to reveal the offshore biogeochemical mechanism of nutrient cycle and its control strategy, and to analyze the long-term records of the coastal ecosystem evolution. Third, we should pay attention to the cause, harm and countermeasure of water hypoxia and acidification in estuaries and bays, and reveal the evolution of toxic algae and its influence on the coastal ecosystem. The basic research on the early warning and forecasting of coastal ecological disasters should also be further enhanced. We need to improve the three-dimensional monitoring of coastal ecosystems and information sharing of ecological disasters as well. Lastly, further efforts are demanded for studying the trends of fishery productivity, analyzing the dynamics of food web structure and its effect on food production, and carrying out the ecosystem level comprehensive research on fishery management.

4.5. Prediction and projection of ecosystem variations

The prediction of short-term fluctuations of the China seas/coasts ecosystem, as well as the projection of long-term trends of the system under global climate change, is a primary goal of ecosystem research and should be greatly enhanced. To achieve this goal, we need to have an integrated understanding of the interaction mechanisms among the physical, chemical and biological processes, and to strengthen the predictive skills by developing coupled models such as the Dynamic Bioclimate Envelope Model (Cheung et al., 2009). For instance, taking the main marine economic fish and invertebrates in China seas/coasts as the key research object, we can apply the newest Bioclimate Envelope Model to predict the effect of future climate change on these marine species in particular and the marine ecosystem in general, thus providing scientific basis for the formulation of climate change polices and measures. For coastal ecosystems, more work needs to be done to develop physical-biogeochemical coupled predictive models based on findings from multi-stressor experiments, both in the field and in the laboratory. Model constructions require information from multifactorial experiments performed on communities (preferably in the field), on time scales of months to years in order to take into consideration the processes of biological acclimation and adaptation. Early warning and emergency response system for major coastal pollution and incidents should be developed based on the predictive models and ecological indicators.

4.6. *Marine ecosystem-based management*

Multiple activities affect the marine environment in concert, yet current management primarily considers activities in isolation (Halpern et al., 2008). Awareness of the need to improve existing management has led to a shift toward ecosystem-based approaches to marine management and conservation. Marine ecosystem-based management involves recognizing and addressing interactions among different spatial and temporal scales, within and among ecological and social systems, and among stakeholder groups and communities interested in the health and stewardship of coastal and marine areas (Leslie and McLeod, 2007). Based on the cognition of the effects of human activity and climate change on the marine and coastal ecosystems, we should take the ecosystem structure and function stability as the core of research. With the ecosystem balance and health as the objective, we should strive for achieving a breakthrough in the development of an ecosystem level integrated coastal management system.

5. Sustainability of China seas/coasts: a link to Future Earth

Sustainability of the coasts and oceans is an important part of the sustainable development of China and coincides with the major goal of Future Earth—providing the knowledge and support to accelerate our transformations to a sustainable world. To achieve the sustainability of the China seas and coasts, we need 1) collaborative and multi-disciplinary research with problem-driven and policy-relevant needs, 2) tight integration of natural and social sciences for better information supply to policymakers, and 3) improved co-designed, co-produced governance, policy and management. Chinese ocean scientists have already taken actions along these lines and have made a few significant strides.

5.1. *China future ocean alliance*

China Future Ocean Alliance (CFO) is a national, neutral and independent scientific association, which provides an international, open forum for marine researchers and end-users to share their knowledge and experience. Through its knowledge sharing network, CFO not only highlights the partners' scientific achievements, but also synthesizes and integrates future ocean-related research. CFO had its first kick-off meeting in Tsing Tao, China, 2014 August, concurrently taking place with a Chinese Academy of Science forum on future directions of marine sciences in China. More than 100 scientists from most of the marine institutions in China attended the meeting. One of the significant outputs of this meeting is the proposed China Blue Carbon Plan which will potentially be a guide for the future directions in marine carbon sink research in China. The committee members of the alliance have consented to its objective of cross-disciplinary integration, synergistic innovation, resource sharing and facing the future. To foster collaborative, interdisciplinary research that addresses human-natural marine science issues, to provide guidance for decisionmakers, managers and communities towards marine sustainability and the ultimately sustainable development of the ocean at all scales, are what the CFO pursues (Fig. 1).

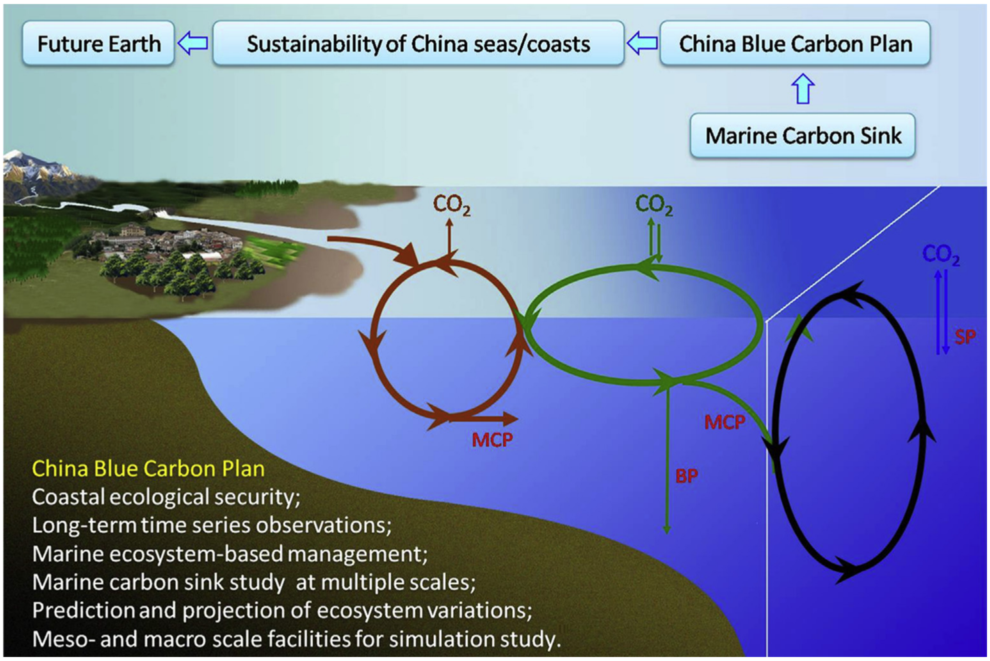

Fig. 1. Main foci of China Future Ocean Alliance and its connection with the Future Earth program (MCP: microbial carbon pump; BP: biological pump; SP: solubility pump).

5.2. Pan-China ocean carbon alliance

The ocean has been discovered to be a large carbon reservoir, and the oceanic carbon storage mechanisms are the vanguard of global warming research. The recognized mechanism that allows for this carbon storage relies on two separate processes: the POC-based biological pump and the dissolved inorganic carbon-based solubility pump. Although research into these two areas of study has proven to be a great success, there still exist many inexplicable and unknown scientific questions and mechanical processes that have yet to be explored. The MCP exposes a new mechanism of carbon storage that does not rely on the sinking of POC and thus offers a potential research-based strategic solution for China to reach its low carbon goals.

A non-profit alliance, the Pan-China Ocean Carbon Alliance (COCA) was established in September, 2013, with members from 21 domestic Chinese institutions including universities affiliated to the Ministry of Education of China, research institutes affiliated to Chinese Academy of Sciences, institutes/centers affiliated to the State Ocean Administration, as well as enterprises including China National Offshore Oil Corporation (CNOOC). COCA aims to become a world leading research cluster on frontiers of ocean carbon sink and related fields. It will act as a platform for joint and interdisciplinary research involving research groups covering biologists, chemists and geologists, and comparative studies between ancient and modern marine environments. By putting the MCP theoretical framework into practical field and laboratory studies, we hope to provide a new, integrated view of microbial mediated carbon flow in the marine environment to fill knowledge gaps in oceanic carbon sequestration.

The major mission of COCA is to set up long-term time series stations for blue carbon monitoring along the Chinese coasts; to establish a series of protocols for core measurements related to marine carbon sinks and to share data. The final goal of COCA is to seek for ocean carbon storage mechanisms by uniting international strengths and make the best of both carbon emission reduction and sink increase through policy−industry−research cooperation strategy.

5.3. LOICZ East Asia Node

Land−Ocean Interactions in the Coastal Zone (LOICZ) is a core project of the International Geosphere−Biosphere Program (IGBP) and the International Human Dimensions Program on Global Environmental Change (IHDP). The Mission of LOICZ is to support transformation to a sustainable and resilient future for society and nature on the coast, by facilitating innovative, integrated and impactful science. It operates as an international research project and global expert network exploring the drivers and socio-environmental impacts of global environmental change in coastal zones. The main goal of LOICZ is “to provide the knowledge, understanding and prediction needed to allow coastal communities to assess, anticipate and respond to the interaction of global change and local pressures which determine coastal change”. As a consequence of the transition of LOICZ into the new Future Earth research initiative project, LOICZ updates its vision and has developed a new ten-year plan for Future Earth Coasts.

The LOICZ East Asia Node (LOICZ EA), officially established at Yantai Institute of Coastal Zone Research, Chinese Academy of Sciences in September 2007, was set up to bring together a large network of scientists and institutions involved in coastal research under the umbrella of LOICZ in China and other Asian countries. The major mission of the LOICZ EA is to promote and coordinate the communication of national researchers, managers, governors and local stakeholders on the management, protection, research, and use of the coastal ecosystem of China (R&D: China Future Coast); to provide a platform and enhance the communication and cooperation for the scientists and governors from the East Asia region, the other regional nodes and the Future Earth.

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