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专论与综述

海洋碳循环研究进展

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摘要　海洋碳循环是全球碳循环的重要组成部分，是影响全球变化的关键控制环节。海洋作为一个巨大的碳库，具有吸收和贮存大气CO_2的能力，影响着大气CO_2的收支平衡，研究碳在海洋中的转移和归宿，对于预测未来大气中CO_2含量乃至全球气候变化具有重要意义。综述了海洋CO_2通量，海水中碳的迁移和海洋沉积物及河口通量的研究状况，介绍了生物泵作用，碳循环模型的发展以及分析方法的最新发展等，并展望了海洋碳循环研究的未来发展趋势。

关键词　海洋；碳循环；海-气通量；DOC；POC；生物泵；海洋模式
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Adavances of studies on marine carbon cycle

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Abstract Marine carbon cycle is the mostly important part of the global carbon cycle，which is the key to controlling the changes of the global climate. The oceans are a huge reservoir of carbon and have the capacity for absorbing and retaining CO2, which plays an important role in regulating the levels of atmospheric CO_2. The study of carbon transfer and carbon end-result in the ocean would help us to forecast the concentrations of atmospheric CO_2 in the future, and also the changes of global climate. This paper presents the main advances in research on the marine carbon cycle and biogeochemical processes, which include the air-sea CO_2 exchange process, the carbon vertical and horizontal transfer in seawater, the carbon flux between seawater and sediment, the input flux of the river and the marine carbon cycle model etc. The total inorganic carbon (TIC) is the main carbon species in seawater, whose concentration is about 1.5～2.5 mmol/kg. The air-sea CO_2 flux is about 1.6～2.0GtC/a calculated from formula and model. There is still some controversy over the exact figure and its future changes, especially if it involves considerable uncertainty such as the function of air-sea CO_2 transfer coefficient which incorporates with many physical factors. The uptake capacity for CO_2 varies significantly due to many factors: solubility of CO_2, seawater partial pressure, carbonate system of mixed layer, temperature, salinity and alkalinity. All of these are various in different seawater, which would act as carbon source or sink of atmospheric CO_2, along with the influence of seasonal and inter-annual variability. The vertical transfer of carbon in seawater is mostly various and complex processes, but mainly depends on the biological pump. The atmospheric CO2 is translated into dissolved organic carbon (DOC) and particulate organic carbon (POC) by photosynthesis of phytoplankton and biology metabolism, which is pumped into the deep seawater by food chain processes, physical mixing, transport and gravitational se ttling. The primary production of global marine ranges from 36.5GtC/a to 103GtC/a, but the majority of which is recycled within the euphotic zone supplying a standing stock of marine microorganisms. It is also estimated that for primary production about 4GtC/a to 20GtC/a is exported to the deep ocean. The major part of export production pumped into the deeper seawater column is also remineralized during sinking; only 0.03% to 0.8% of primary production can be delivered to the sediment. The concentrations of DOC and POC usually are very abundant in surface and subsurface of most oceans, and decrease with the depth of seawater, however, they will keep a lower constant value in deep seawater. The contents of DOC in seawater range from 60μmol/L C to 90μmol/L C in the surface, about 40μmol/L C in the deep. The distributions of DOC and POC show a decreasing trend from the inner shelf to the slope and to open sea because of the river inputs and higher primary productivity. The carbon benthic flux of seawater-sediment interface is one of the important aspects of marine carbon cycle. The remineralization of POC in the sediment and the diffusion of DOC across the sediment-water interface can increase the concentrations of DOC and DIC; enrich the dissolved nutrients in deep seawater. The nutrient-enriched deep seawater also is taken to the surface by the adverse/diffusive upwelling and recycles in the euphotic zone by biological activities. Carbon derived from land also enters into the ocean via river as well as to some extent via groundwater; the global natural transport flux from river to the ocean is about 0.8GtC/a. The marine carbon cycle model has been built up to stimulate all kinds of physical, chemical and biological processes in the ocean. The model forecasts the atmosphere conditions in the pre-industrial and the climate changes in the future, and also estimates the controlling functions of increasing CO_2 concentrations into the ocean. The model includes a lot of styles such as BM, GCM and B-GCM etc, and develops from one dimension to three dimensions. The three dimensional biological geochemistry model would be the important and efficient tool for studying the marine carbon cycle. The latest development of determining DOC and POC, and the future for the direction of marine carbon cycle is also summarized in the paper.

Key words marine _ carbon cycle _ air-sea exchange _ DOC _ POC _ biological pump _ ocean model

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