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厦门大学

硕 士 学 位 论 文

台湾海峡 CDOM 对台风及 ENSO 事件的响应

Response of Colored Dissolved Organic Matter to the Typhoon and ENSO events in the Taiwan Strait

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摘要

在全球变化的大背景下，台风暴雨、厄尔尼诺-南方涛动（El Nino- Southern Oscillation，ENSO）等气候异常事件频发，对边缘海溶解有机物（DOM）的生物地球化学循环产生重要影响，但目前有关边缘海 DOM 的研究大多侧重于常态天气条件，缺乏极端事件对边缘海 DOM 源、汇格局的影响及其机制的深入研究。台湾海峡地处西太平洋亚热带海域，台风暴雨事件频发，水团运动、生物生产力与 ENSO 事件也有明确的关联，因此是研究上述科学问题的理想场所。本论文以九龙江口-台湾海峡交界区和台湾海峡南部海域为研究区域，以 DOM 的吸收光谱和荧光光谱为分析表征手段，分别探讨了九龙江口-台湾海峡交界区有色溶解有机物（CDOM）对 2014 年夏季台风“麦德姆”事件的响应、以及 2015-2016 年强 ENSO 事件对台湾海峡南部海域 CDOM 来源、分布及光谱特性的影响。主要结果如下：

（1）“麦德姆”台风引发的九龙江流域暴雨径流导致河口端 CDOM 丰度及其荧光组分强度显著增加，但由于河流-河口界面的去除过程以及潮汐作用的影响，这些流域的强信号并未在河口下游区域有明显的体现，总体上暴雨事件引起的河口羽流局限于近岸海域。

（2）“麦德姆”台风过程对九龙江河口-海峡交界区的水团分布格局及其生态效应有显著影响，并进而影响了该区域 CDOM 的来源和组成特征。台风事件之后，交界区的温度、盐度表现为“三明治”式分布特征，即近岸为高温低盐的九龙江河口羽流，中间为上升流区，远岸表现为高温低盐的珠江羽流特征。与之对应，台风事件之后九龙江口羽流带来的陆源信号、上升流引发的水华所产生的自生源信号以及外来输入的珠江羽流信号是该区域 CDOM 的主要来源。由于台风之前现场自生源的贡献较大，导致台风之后河口-海峡交界区表层 CDOM 的平均丰度反而低于台风之前。

（3）2015-2016 年超强 ENSO 事件期间，珠江入海径流量明显增加，这导致夏季台湾海峡南部海域水体中珠江冲淡水所占的比例显著增加。2016 年 7 月台湾海峡南部海域珠江冲淡水的占比高达 4.3%，远高于 2010 年 6 月（弱 ENSO 事件期间）的 1.4%，和 2014 年 7 月（超强 ENSO 事件之前）的 2.2%。与之对应，2016 年夏季台湾海峡南部海域表层 CDOM 的丰度也最高，为 0.96 m^{-1}，高

于 2010 年的 0.69 m^{-1} 和 2014 年的 0.90 m^{-1}。

（4）夏季台湾海峡南部海域水团表现为三端元混合特征，包括珠江羽流、南海表层水和南海深层水。伴随珠江羽流的增强，夏季来自调查海域南部的珠江羽流对台湾海峡南部海域 CDOM 的贡献从 2010 年的 0.93%增加到 2016 年的 32.7%，同时调查海域水体中来自现场生物活动、沉积物再悬浮等非物理混合过程贡献的 CDOM 比例从 2010 年、2014 年的 23.9%和 25.8%降低到 2016 年的 15.0%。

（5）2015-2016 年 ENSO 事件期间，汕头和东山沿岸上升流增强，台湾浅滩上升流减弱；同时，汕头和东山上升流区表层 Chl-*a* 的浓度在 2016 年的夏季表现最高，东山上升流海域表层 Chl-*a* 的浓度甚至高达 8.22 μg/L，远高于 2010 年的 1.60 μg/L 和 2014 年的 0.23 μg/L。与之对应，2016 年夏季东山沿岸上升流海域 CDOM 中生物来源贡献较高，但 2016 年夏季东山沿岸上升流对 CDOM 的总体贡献（Δa_{280}= 0.33 m^{-1}）低于 2014 年（Δa_{280}= 0.77 m^{-1}）。2016 年夏季汕头沿岸上升流海域 CDOM 丰度甚至低于调查海域的平均值，与远岸海域 CDOM 水平相当，显示不同上升流海域有机碳循环过程对 ENSO 事件的响应存在差异。

关键词：厄尔尼诺-南方涛动；台风事件；台湾海峡；有色溶解有机物

Abstract

Unusual or extreme climate events like typhoon, El Nino Southern Oscillation (ENSO) events happen frequently in the context of global change. Such events undoubtedly have important impacts on the biogeochemical cycle of dissolved organic matter (DOM) in the marginal seas. However, most studies in this field focused on the normal climate conditions, leaving a great blank on how the extreme events will influence the sources-sink issue of coastal DOM cycle. The Taiwan Strait is located in the subtropical region of the Western Pacific, where typhoon and rainstorm events happen frequently. Previous studies also found that the watermass movement and primary productivity of the Taiwan Strait was significantly influenced by ENSO events. Thus, this sea area is an ideal place to study the response of marine DOM dynamics to these extreme events. In this paper, Jiulong Estuary-Taiwan Strait junction area and the Southern Taiwan Strait was selected as the investigation areas. The absorption and fluorescence spectra was used to characterize the DOM properties. The impact of Typhoon Matmo occurred in summer 2014 and 2015-2016 strong ENSO event on CDOM sources, distribution and spectral characteristics of the Jiulong Estuary-Taiwan Strait junction area and the Southern Taiwan Strait were studied, respectively. The main results are as follows:

(1) CDOM and FDOM abundance in the upper Jiulong Estuary increased significantly as a response to the heavy precipitation in the watershed triggered by Typhoon Matmo. However, these signals were weakened in the downstream of the estuary as a result of removal process occurred in the river-extuary interface and mixing process by the tidal movement. The estuarine plume signal derived from this event was only limited in the inshore area.

(2) Typhoon “Matmo” had significant impacts on hydrological and biological process of the Jiulong Estuary-Taiwan Strait junction area, which will influence the source and composition of CDOM in this area. After Typhoon Matmo, the distribution of temperature and salinity in study area showed a sandwich-like model: high temperature and low salinity in inshore area, low temperature and high salinity in the

middle area and high temperature and low salinity in offshore area. As a result, terrestrial input, autochthonous contribution from the algal bloom in upwelling zone and long-distance transport from the Pearl River plume were main sources of CDOM in the study area after Typhoon "Matmo". However, due to the much higher contribution of in situ biological activities before Typhoon "Matmo", the average abundance of surface CDOM in the study area was not increased after the thphoon process.

(3) Since the runoff of the Pearl River increased significantly in 2015-2016 under the influence of the 2015-2016 super ENSO event, The contribution of the Pearl river water plume in the Southern Taiwan Strait increased to 4.3% in 2016, compared to the 1.4% in 2010 (weak ENSO event) and 2.2% (before the super event). Accordingly, the CDOM abundance was also highest in summer of 2016 (0.96 m^{-1}), compared with the 0.69 m^{-1} in summer of 2010 and 0.90 m^{-1} in summer of 2014.

(4) The summer hydrology in the Southern Taiwan Strait follows a three-end member mixing model. The three end members are the Pearl River plume, the South China Sea Surface Current and the South China Sea Subsurface Current. The contribution of the Pearl River plume to the CDOM pool in the Southern Taiwan Strait increased from 0.93% in 2010 to 32.7% in 2016. Contributions from processes like biological activities and sediment resuspension decreased from 23.9% in 2010 and 25.8% in 2014 to15.0% in 2016.

(5) The Shantou and Dongshan coastal upwelling enhanced while the Taiwan Bank upwelling weakened during 2015-2016 super ENSO event. Chl-*a* was highest (8.22 μg/L) in surface water of Shantou and Dongshan upwelling area in the summer of 2016, much higher than in 2010 (1.60 μg/L) and in 2014 (0.23 μg/L). Thus, the biological contribution to the CDOM pool was also very high in summer, 2016. However, the overall contribution of Dongshan upwelling to CDOM pool was lower in 2016 (Δa_{280}= 0.33 m^{-1}) than 2014 (Δa_{280}= 0.77 m^{-1}). The CDOM abundance in Shantou and Dongshan upwelling area in 2016 was even lower than the average value of the whole study area in the summer of 2016, demonstrated the different response of upwellings in different area of Southern Taiwan Strait to 2015-2016 ENSO event.

Key words: ENSO; Typhoon; Taiwan Strait; CDOM