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# Influences of the alternation of wet-dry periods on the variability of chromophoric dissolved organic matter in the water level fluctuation zone of the Three Gorges Reservoir area, China

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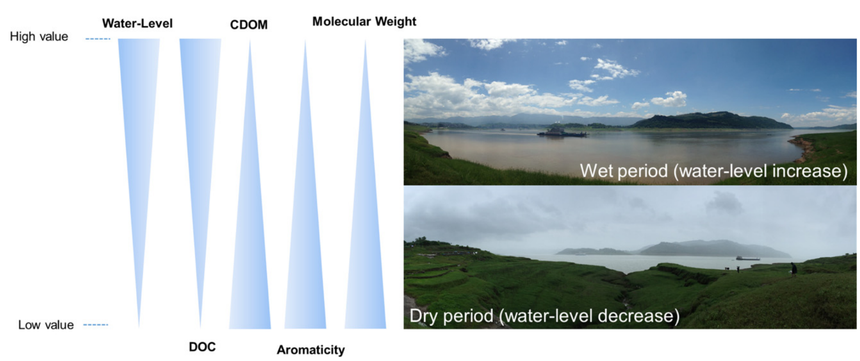
## HIGHLIGHTS

- The alternation of wet and dry periods is formed by water level fluctuations in the TGR area.
- Wet-dry period alternations significantly influence the quantity and quality of DOM.
- Higher DOC and lower CDOM with a lower aromaticity were observed in the wet period.
- The temporal variation of DOM is significant compared to the spatial variation.
- Changes in aromatic components control the dynamics of DOC and the abundance of CDOM.

## GRAPHICAL ABSTRACT

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## ABSTRACT

Dissolved organic matter (DOM) is a crucial driver of various biogeochemical processes in aquatic systems. Thus, many lakes and streams have been investigated in the past several decades. However, fewer studies have sought to understand the changes in DOM characteristics in the waters of the Three Gorges Reservoir (TGR) areas, which are the largest artificial reservoir areas in the world. Thus, a field investigation of dissolved organic carbon (DOC) concentrations and of chromophoric dissolved organic matter (CDOM) properties was conducted from 2013 to 2015 to track the spatial-temporal variability of DOM properties in the TGR areas. The results showed that the alternations of wet and dry periods due to hydrological management have a substantial effect on the quantity and quality of aquatic DOM in TGR areas. Increases in DOC concentrations in the wet period show an apparent "dilution effect" that decreases CDOM compounds with relatively lower aromaticity (i.e., $SUVA_{254}$) and molecular weight (i.e., $S_R$). In contrast to the obvious temporal variations of DOM, significant spatial variability was not observed in this study. Additionally, DOM showed more terrigenous characteristics in the dry period but weak terrigenous characteristics in the wet period. Furthermore, the positive correlation between $SUVA_{254}$ and CDOM suggests that the aromatic component controls the CDOM dynamics in TGR areas. The first attempt to investigate the DOM dynamics in TGR areas since the Three Gorges Dam was conducted in 2012, and the unique patterns of spatial-temporal variations in DOM that are highlighted in this study might provide a new insight for understanding the role of DOM in the fates of contaminants and may help in the further management of flow loads and water quality in the TGR area.



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## 1. Introduction

Dissolved organic matter (DOM) is a fraction of natural organic matter (NOM) in the earth system. DOM is ubiquitous in inland waters such as rivers, lakes, and reservoirs; thus, DOM plays a pivotal role in the aquatic environment and has a significant influence on the global carbon cycle (Tranvik et al., 2009; Nelson and Siegel, 2013). In addition, it also significantly influences the biogeochemical cycling of pollutants such as trace heavy metals and persistent organic pollutants because of its active properties involving various functional groups (Aiken et al., 2011; Hsu-Kim et al., 2013; Gu et al., 2011; Jiang et al., 2015). As an important part of bulk DOM, chromophoric DOM (CDOM), also called colored DOM, has been the subject of continuous studies for decades (Coble, 2007; Tranvik et al., 2009; Nelson and Siegel, 2013; Solomon et al., 2015). Because of its optical properties and influences on water colour, some important measures for CDOM studies in ocean and inland waters are satellite remote sensing and *in situ* water quality monitoring. Using CDOM to estimate the spatial-temporal distributions of dissolved organic carbon (DOC) and aquatic biomass are essential methods that are currently being improved. Additionally, the high photochemical reactivity of CDOM makes it important in photochemistry and photobiology, which results in an intimate association of aquatic system primary productivity and ecosystem stability (Häder et al., 2011, 2015). Furthermore, as a bridge linking the carbon cycle and the environmental fate of contaminants, the dynamics of DOM can also enhance our understanding of environmental pollution in the context of climate change (Aiken et al., 2011; Solomon et al., 2015; Jonsson et al., 2017). Thus, tracing and understanding the complex characteristics of DOM is critical to further unveiling its environmental and ecological role in the aquatic environment. Importantly, environmental concerns related to water quality safety and pollution events further motivate the evaluation of the variability of DOM in a given region. In recent years, interest in CDOM properties and cycling in aquatic systems has rapidly increased because this optical information provides rich information to reflect the biogeochemical characteristics of DOM and its environmental implications (Coble, 2007; Helms et al., 2008; Tranvik et al., 2009; Nelson and Siegel, 2013; Hansen et al., 2016; Jiang et al., 2017). Among the analytical tools for determining the heterogeneous structures of DOM (Leenheer and Croué, 2003), optical absorption properties have been increasingly used to reveal DOM characteristics and the influences of DOM on contaminants (Weishaar et al., 2003; Wei et al., 2008; Aiken et al., 2011; Jiang et al., 2017) as these tools have a low cost, are fast, and are straightforward.

As the largest power station with an installed capacity of 22,500 MW, the Three Gorges Dam (TGD) was completed and fully functional in July of 2012. The Three Gorges Reservoir (TGR), formed by the construction of the TGD, is the largest artificial reservoir area in the world. Because of artificial hydrological adjustment, the water level of TGR fluctuates by approximately 30 m (ranged from 145 to 175 m asl), which results in an area of 306.33 $km^2$ of periodically submerged soils called "TGR water level fluctuation zones" (Bao et al., 2015). In addition to producing electricity for economic development, the TGD is intended to enlarge the shipping capacity in the Yangtze River and control flow loads to reduce the potential risk of flooding downstream. However, from insights into environmental management, water level adjustment in TGR has also raised widespread environmental concerns, including greenhouse gas emissions and soil and water pollution (Wang and Zhang, 2013; Yang et al., 2013c; Lam, 2015; Floehr et al., 2015; Liu et al., 2017). Compared to other natural lakes and streams, the inundation period (i.e., the "wet" period) of TGR occurs in the autumn-winter season and manifests as a water level increase, but the water level decreases beginning in the spring until the summer (i.e., the "dry" period). This unique hydrological process, called "alternation of wet and dry," highlights the variability in DOM from different origins and biogeochemical processes, which strongly indicates that the aquatic DOM in the TGR area is closely associated with this hydrological process. Furthermore, lentic and lotic aquatic environments formed during the alternation of wet and dry periods, and their linkage within the DOM dynamics further resulted in a series of environmental biogeochemical processes, posing a challenge to the management of flow loads and water quality.

Until now, regional CDOM characteristics have been reported in many studies across diverse aquatic environments (Helms et al., 2008; Jane et al., 2017; Jaffé et al., 2008; Kothawala et al., 2014; Oliver et al., 2016; Spencer et al., 2008, 2009, 2010, 2012, 2014; Stedmon et al., 2011; Wen et al., 2016; Yang et al., 2013a, 2013b; Zhang et al., 2009), but there are few reported case studies in TGR areas. In particular, there is also a lack of reports on whether the alternation of wet and dry periods due to water level fluctuation has a significant influence on CDOM variations since the establishment and beginning of operations of the TGD in 2012. Thus, to fill the knowledge gap, two main questions about DOM geochemical characteristics will be addressed in this study: (1) do the alternations of wet and dry periods obviously influence the spatial variability of CDOM; and (2) is there a temporal difference (i.e., a difference between wet and dry periods) in CDOM influenced by wet-dry alternations? In addition to the determination of CDOM absorption spectral characteristics for tracking DOM dynamics on a spatial-temporal scale, these results may provide further insights into the role of DOM in ecological and biogeochemical processes in TGR areas.

## 2. Materials and methods

### 2.1. Study sites

To investigate the spatial-temporal variability of DOM properties in TGR areas, we selected four sampling sites (Fig. 1) for the long-term DOM monitoring project. Sites in Zhenxi Town of Fulin (FL) and Shibaozhai Town of Zhongxian (SB) were both located in the mainstream of the Yangtze River. These sites were representative of the aquatic system changes in TGR areas (i.e., lotic waters), which have been directly influenced by the water level adjustment operation of the Three Gorges Dam. The other two sites, Tujing County of Zhongxian (TJ) and Hanfeng of Kaixian (KX), were selected because both are typical backwater zones (i.e., lentic waters) formed by the alteration of wet and dry periods, and surface water can be collected year-round. Regarding the riparian land-use types, FL and SB sites are adjacent to agricultural watersheds; the KX site is adjacent to a suburban landscape influenced by residential and agricultural activities, and TJ is a mixture of evergreen broad-leaf forest and agricultural lands. In this study, we only consider the mainstream (i.e., FL and SB) and backwater zones (i.e., KX and TJ) but not tributaries, because both are very heavily and directly influenced by water level fluctuations and are best for reflecting the impacts of wet-dry alternations.

### 2.2. Sampling collection

DOM sample ($n = 335$) collection was conducted from April 2013 to September 2015, during which there were two alternations of wet and dry periods. The sampling campaigns during the wet period were individually carried out in June and September of 2013, July and September of 2014, and July and September of 2015. The sampling campaigns for the dry period were carried out in April and December of 2013, April and December of 2014, and March of 2015. All water samples were collected in acid-washed and samples-rinsed polycarbonate bottles and kept in the cold-storage box for transferring to lab within 1–2 days. When samples arrived, all water samples were filtered in the lab through cellulose acetate filters (0.45 μm) that were pre-rinsed with Milli-Q® water (18.2 Ω cm) within 12 h. Before analysis, all samples were stored in the dark and kept in a refrigerator at 4 °C. For each sampling campaign, all analyses were completed within less than one week