# A systematic examination of the relationships between CDOM and DOC in inland waters in China

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**Abstract:** Chromophoric dissolved organic matter (CDOM) plays a vital role in the biogeochemical cycle in aquatic ecosystems. The relationship between CDOM and dissolved organic carbon (DOC) has been investigated, and the significant relationship lays the foundation for the estimation of DOC using remotely sensed imagery data~~. An algorithm has been developed to retrieve DOC via CDOM absorption ($a_{CDOM}$) at 275 and 295 nm for coastal waters, but it is still unclear for the relationship between DOC and $a_{CDOM}$ in other types of waters~~. The current study examined the samples from freshwater lakes, saline lakes, rivers and streams, urban water bodies, and ice-covered lakes in China for tracking the variation of the relationships between DOC and CDOM. The regression model slopes for DOC versus $a_{CDOM}$(275) ranged from extreme low 0.33 (highly saline lakes) to 1.03 (urban waters) and 3.~~13~~ 01 (river waters). The low values were observed in saline lake waters and waters from semi-arid or arid regions where strong photo-bleaching is expected due to thin ozone layers, less cloud cover, longer water residence time and daylight hours. In contrast, high values were found in waters developed in wetlands or forest in Northeast China, where ~~massive~~more organic matter was transported from catchment to waters. The study also demonstrated that stronger relationships between CDOM and DOC were revealed when $a_{CDOM}(275)$ were sorted by the ratio of $a_{CDOM}(250)$~~ to ~~/$a_{CDOM}(365)$, which is a tracer for the CDOM absorption with respect to its composition, and the determination of coefficient of the regression models ranged from 0.~~78 ~~75 to 0.~~99 ~~98 for different groups of waters. Our results indicated the relationships between CDOM and DOC are variable for different inland waters, ~~and therefore remote sensing~~thus models for DOC estimation through linking with CDOM absorption need to be tailored according to water types.

**Keywords:** Absorption, CDOM, DOC, regression slope, saline water, fresh water

# 1. Introduction

~~Compared with other terrestrial ecosystems, e.g., forest and grassland, i~~Inland waters ~~only occupy a small fraction (3.5%) of the earth surface (Verpoorter et al., 2014). However, they~~ play a disproportional role for the global carbon cycling with respect to carbon transportation, transformation and carbon storage (Tranvik et al., 2009; Raymond et al., 2013; Verpoorter et al., 2014; Yang et al., 2015).~~ According to Tranvik et al. (2009), 2.9 Pg C was transported from terrestrial ecosystems to inland waters every year, of which about 0.6 Pg C was buried in the lake sediment, 1.4 Pg C was released into the air as $CO_2$ or $CH_4$, and the rest of 0.9 Pg C was exported to the ocean via river channels.~~ However, the amount of dissolved organic carbon (DOC) stored in the inland waters is still unclear or the uncertainty is still needed to be evaluated (Tranvik et al., 2009). Determination DOC concentration is straightforward through field sampling and laboratory analysis (Findlay and Sinsabaugh, 2003). However, there are millions of lakes in the world, and many of them are remote and inaccessible, making it impossible to evaluate DOC concentration using routine approach (Cardille et al., 2013; Brezonik et al., 2015; Pekel et al., 2016). Researchers have found that remote sensing might provide a promising tool for quantification of DOC of inland waters at large scale through linking DOC with chromophoric dissolved organic matter (CDOM), particularly for ~~these~~ inland waters situating in remote ~~region~~ area with less accessibility (~~Cole et al., 2007;~~ Tranvik et al., 2009; Kutser et al., 2015; Brezonik et al., 2015).

~~CDOM is one of the largest bioactive reservoirs of organic matter on the earth (Para~~

~~et al., 2010), influencing light transmittance in aquatic ecosystems (Vodacek et al., 1997; Williamson and Rose, 2010).~~ As one of the optically active constituents (OACs) in waters, CDOM can be estimated through remotely sensed signals (Yu et al., 2010; Kutser et al., 2015), and is acted as a proxy in many regions for the amount of DOC in the water column. As shown in Fig.1, CDOM and DOC in the aquatic ecosystems are mainly originated from external (allochthonous) and internal (autochthonous) sources, in addition to directly discharge from anthropogenic activities (Zhou et al., 2016). Generally, the autochthonous CDOM is essentially originated from algae and macrophytes, and mainly consists of various compounds of low molecular weights (Findlay and Sinsabaugh, 2003; Zhang et al., ~~2009~~2010). While, the allochthonous CDOM is mainly derived from the surrounding terrestrial ecosystems, and it comprises a continuum of small organic molecules to highly polymeric humic substances~~ with compounds typically ranging from 100 to 100,000 Da~~. In terms of CDOM originates from anthropogenic, it contains fatty acid, amino acid and sugar, thus the composition of CDOM is more complex than that from natural systems (Zhou et al., 2016; Zhao et al., 2016a). Hydrological factors also affect~~s~~ the DOC and CDOM characteristic~~. The concentrations of and the relationship between CDOM and DOC in river waters depend on many factors, in which the water type, the seasonality and climatology, the typology of the water, the surrounding landscapes.~~ and ~~P~~particularly, the discharge and catchment area are the ~~most~~ important ones (Neff et al., 2006; Spencer et al., 2012~~; Alvarez-Cobelas et al., 2012~~).

**[Insert Fig.1 about here]**

CDOM is a ~~major~~ light-absorbing ~~substance~~constituent, which is partially responsible for ~~much of~~ the color in waters (Bricaud et al., 1981; Reche et al., 1999; Babin et al., 2003). The chemical structure and origin of CDOM can be characterized by its absorption coefficients ($a_{CDOM}(\lambda)$) and spectral slopes (De Haan and De Boer, 1987; Helms et al., 2008). Weishaar et al. (2003) has proven that the carbon specific absorption coefficient at 254 nm, e.g., $SUVA_{254}$ is a good tracer for the aromaticity of humic acid in CDOM, while the ratio of CDOM absorption at 250 to 365 nm, i.e., ~~(~~$a_{CDOM}$(250)/$a_{CDOM}$~~/~~(365), herein, M value,~~s)~~ has been successfully used to track the changes in DOM ~~molecule~~ molecular weight (De Haan and De Boer, 1987~~; Zhang et al., 2010) and absorption intensity (Song et al., 2013~~). Biodegradation and photodegradation are the major processes to determine the transformation and composition of CDOM (Findlay and Sinsabaugh, 2003; Zhang et al., 2010), which ultimately affect the relationship between DOC and CDOM (Spencer et al., 2012; Yu et al., 2016). With prolonged sunlight ~~absorbed by CDOM~~radiation, some of the colored fraction of CDOM is lost by the photobleaching processes (Miller et al., 1995; Zhang et al., 2010), which can be measured by the light absorbance decreasing at some specific (diagnostic) wavelength, e.g., 250, 254, 275, 295, 360 ~~365 or~~and 440 nm.

It should be noted that $a_{CDOM}(440)$ is usually used by remote sensing community due to this wavelength is ~~less affected~~ overlapped ~~by~~with ~~phytoplankton~~pigment absorption at 443 nm~~(Lee et al., 2002)~~, thus reporting $a_{CDOM}(440)$ has potential to improve chlorophyll-a estimation accuracy (Lee et al., 2002). Under this circumstance, the relationship between CDOM and DOC varies since CDOM loses color while the variation of DOC concentration is almost negligible. Saline or brackish lakes in the arid or semi-arid regions generally expose to longer sunlight radiation, thus CDOM absorbance decreases, while DOC is accumulated due to the longer residence time (Curtis and Adams~~et al.~~, ~~1997~~1995; Song et al., 2013; Wen et al., 2016). Compared to photodegradation on CDOM, the biodegradation processes by microbes are much complicated, and extracellular enzymes are the key substance required to decompose the high-molecular-weight CDOM into low-molecular-weight substrates (Findlay and Sinsabaugh, 2003~~; Romera-Castillo et al., 2012~~). With compositional change, the absorption feature of CDOM and its relation to DOC varies correspondingly, but the relationship between CDOM and DOC is far from solved (Gonnelli et al., 2013). In addition, the SUVA$_{254}$ and ~~$a_{CDOM}$(250/365)~~M value may be used to classify CDOM into different groups and enhance the relationship with DOC based on CDOM absorption grouping.

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Some studies have ~~researched~~ investigated the spatial and seasonal variations of CDOM and DOC in ice free season in lakes, rivers and oceans (Vodacek et al., 1997; Neff et al., 2006; Stedmon et al., 2011; Brezonik et al., 2015), but less is known about saline lakes (Song et al., 2013; Wen et al., 2016). Even less is known~~, particularly~~ about urban waters influenced by sewage effluent and waters with ice cover in winter (Belzile et al.~~, 2000,~~ 2002; Zhao et al~~b.~~., 2016b).~~ The relationship between DOC and CDOM lays the foundation for the remote sensing estimation of DOC in both inland waters (Yu et al., 2010; Griffin et al., 2011; Zhu et al., 2014; Brezonik et al., 2015) and marine (Hoge et al., 1996; Bricaud et al., 2012; Nelson et al., 2012).~~ The significant relationship between CDOM and DOC was observed in the Gulf of Mexico, and stable regression model was established between DOC and $a_{CDOM}(275)$ and $a_{CDOM}(295)$ (Fichot and Benner, 2011). Similar results were also found in other estuaries along a salinity gradient, for example the ~~Finish Gulf~~Baltic Sea surface water (Kowalczuk et al., 20~~06~~10) and the Chesapeake Bay (Le et al., 2013). However, Chen et al. (2004) found that the relationship between CDOM and DOC was not conservative due to estuarine mixing or photo-degradation. Similar arguments were raised for Congo River ~~(Spencer et al. 2009)~~ and waters across mainland USA (Spencer et al., 2009, 2012). ~~The study on the relationship between DOC and CDOM in Lake Taihu found a relatively stable relationship for water samples collected in different seasons except winter (Jiang et al. 2012).~~ However, seasonal variations were observed in some studies due to the mixing of various endmembers of CDOM from different terrestrial ecosystems and internal source (Zhang et al., 2010; Spencer et al., 2012; Yu et al., 2016; Zhou et al., 2016). ~~Along with laboratory measurements, portable instruments deployed in river or streams provide great potential to quantify DOC and CDOM at very dynamic manner (Lee et al., 2015; Yu et al., 2016).~~

~~According to Fig.1, the proposed hypothesis suggests that the main source of CDOM and DOC in different waters vary, coupled with biogeochemical processes (photobleaching and microbial degradation), resulting in the compositional differences, and ultimately affects CDOM absorption and its relationship with DOC. Hydrological feature and anthropogenic processes further cause the relationship between CDOM and DOC varies both in time and space. Remote sensing technology has increasingly played~~

~~a vital role in quantifying carbon cycling in inland waters (Tranvik et al., 2009; Raymond et al., 2013). However, the prerequisite is to systematically examine the relationship between CDOM and DOC.~~ In this study, the characteristics of DOC and CDOM in different inland waters across China were examined to determine the spatial feature associated with landscape variations, hydrologic conditions and saline gradients. The objectives of this study are to: 1) examine the relationship between CDOM and DOC concentrations across a wide range of waters with various physical, chemical and biological conditions, and 2) develop a model for the relationship between DOC and CDOM based on the sorted CDOM absorption feature, e.g., the ~~ratio of $a_{\text{CDOM}}$(250/365)~~ M value with aiming to improve the regression modeling accuracy.

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## 2. Materials and Methods

The dataset is composed of five subsets of samples collected from various types of waters across China (Table 1, Fig.2), which encompassed a wide range of DOC and CDOM. The first dataset (n = 288; from early spring 2009 to late October 2014) includes samples collected in freshwater lakes and reservoirs during the growing season with various landscape types. The second dataset (n = 345; from early spring 2010 to late mid-September 2014) includes samples collected in brackish to saline water bodies. The third dataset (n =322; from early May 2012 to late October 2014) includes samples collected in rivers and streams across different basins in China. In addition, 69 samples were collected from three sections along the Songhua Rive, the Yalu and the Hunjiang River during the ice free period in 2015 to examine the impact of river flow on the relationship between DOC and CDOM (see Fig.S1 for location). The fourth dataset (n = 328; from 2011 to 2014 in the ice frozen season) includes samples collected in Northeast China in winter from both lake ice and underlying waters. The fifth dataset (n = 221; from early May 2013 to mid-October 2014) collects samples in urban water bodies, including lakes, ponds, rivers and streams, which were severely polluted by sewage effluents. City maps and Landsat imagery data acquired in 2014 or 2015 were used to delineate urban boundaries with ArcGIS 10.0 (ESRI Inc., Redlands, California, USA), and water bodies in these investigated cities constrained by urban boundaries were considered as urban water bodies. Except river samples, the sampling dates, water body names and locations of other types of water bodies were provided in supplementary Table S1-3.

**[Insert Fig.2 about here]**

### 2.1 Water quality determination

Water samples were collected approximately 0.5m below the water surface at each station, generally locating in the middle of water bodies. Water samples were collected in two 1 L amber HDPE bottles, and kept in coolers with ice packs in the field and kept in refrigerator at 4℃ after shipping back to the laboratory~~; ~~. ~~a~~All samples were preprocessed (e.g., filtration, pH and electrical conductivity (EC) determination) within two days in the laboratory. Water salinity was measured using DDS-307 EC meter (µS/cm) at room temperature (20±2℃) and converted to *in situ* salinity, expressed in practical salinity units (PSU), in the laboratory. Water samples were filtered using Whatman cellulose acetone filter with pore size of 0.45 µm. Chlorophyll-a (Chl-a) was extracted and concentration was measured using a Shimadzu UV-2600~~2050~~PC spectrophotometer, the details can be found in ~~(Song et al., 2013)~~Jeffrey and Humphrey (1975). Total suspended matter (TSM) was determined gravimetrically using pre-combusted Whatman GF/F filters with 0.7μm pore size, details can be found in Song et al. (2013). DOC concentrations were measured by high temperature combustion (HTC) with water samples filtered through 0.45 μm Whatman cellulose acetone filters (~~Song et al., 2013;~~ Zhao et al., 2016a). The standards for dissolved total carbon (DTC) were prepared from reagent grade potassium hydrogen phthalate in ultra-pure water, while dissolved inorganic carbon (DIC) were determined using a mixture of anhydrous sodium carbonate and sodium hydrogen carbonate. DOC was calculated by subtracting DIC from DTC, both of which were measured using a Total Organic Carbon Analyzer (TOC-VCPN, Shimadzu, Japan). Total nitrogen (TN) was measured based on the absorption levels at 146 nm of water samples decomposed with alkaline potassium peroxydisulfate. Total phosphorus (TP) was determined using the molybdenum blue method after the samples were digested with potassium peroxydisulfate (APHA, 1998). pH was measured using a PHS-3C pH meter at room temperature (20±2℃).

## 2.2 CDOM absorption measurement

All water samples were filtered at low pressure at two steps: 1) filtered at low pressure through a pre-combusted Whatman GF/F filter (0.7μm), and 2) further filtered through pre-rinsed 25 mm Millipore membrane cellulose filter (0.22 μm). Absorption spectra were obtained between 200 and 800 nm at 1 nm increment using a Shimadzu UV-2600PC UV-Vis dual beam spectrophotometer (Shimadzu Inc., Japan) through a 1 cm quartz cuvette (or 5 cm cuvette for ice melted water samples). Milli-Q water was used as reference for CDOM absorption measurements. The Napierian absorption coefficient ($a_{\text{CDOM}}$) was calculated from the measured optical density ($OD$) of samples using Eq. (1):

$$a_{CDOM}(\lambda) = 2.303[OD_{S(\lambda)} - OD_{(null)}]/\beta \qquad (1)$$

where $\beta$ is the cuvette path length (0.01 or 0.05m) and 2.303 is the conversion factor of base 10 to base *e* logarithms. To remove the scattering effect from the limited fine particles remained in the filtered solutions, a necessitated correction was implemented by assuming the average optical density over 740–750 nm to be zero (Babin et al., 2003). ~~All absorption measurements were conducted within 48 h after the samples were shipped back to the laboratory. In addition, ~~SUVA$_{254}$ and ~~$a_{\text{CDOM}}$(250/365)~~M values were calculated to characterize CDOM with respect to their compositional features. In addition, ~~and group ~~$a_{\text{CDOM}}$ was divided into different groups according to M values by hierarchical cluster approach, which was performed in SPSS software package with the pairwise distance between samples was measured by squared Euclidean distance and the clusters were linked together by Ward’s linkage method (Ward Jr, 1963). The method has been applied to classify the waters into different types according the remote sensing spectra (Vantrepotte et al., 2012; Shi et al., 2013).~~, with respect to their compositional features and try to link DOC based on CDOM grouping.~~

## 3. Results~~ and discussion~~

### 3.1. ~~Biological and geochemical~~Water quality characteristics

~~The biological and geochemical properties in the water bodies are diverse. ~~Chl-a

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concentrations (46.44±59.71 μg/L) changed from 0.28 to 521.12μg/L~~, with the mean of 46.44 μg/L~~. TN and TP concentrations were very high in fresh lake~~ water~~s, saline lakes~~ water~~ and particularly urban water bodies (Table 1)~~, indicating that most of the waters are heavily eutrophic~~. It is worth noting that Chl-a concentration was still high 7.3±19.7μg/L even in ice-covered lakes in winter from Northeast China~~, which resulted from high TN (4.3±5.4mg/L) and TP (0.7±0.6mg/L) concentrations even under ice cover~~. Electric conductivity (EC) and pH were high in the semi-arid and arid regions, and they were 1067-41000 μs/cm and 7.1-11.4, respectively. ~~This is due to specific regional hydro-geologic and climatic conditions. The results are consistent with previous findings (Song et al., 2013; Wen et al., 2016).~~ Overall, waters were highly turbid with high TSM concentrations (119.55 ± 131.37 mg/L), ~~but there were big~~ and apparent variations were observed for~~between~~ different types of waters (Table 1). Hydrographic conditions exerted strong impact on water turbidity and TSM concentration, thus these two parameters of river and stream samples were excluded in this study (Table 1). ~~Large variations of water quality parameters in the extensive geographic area, for example in China, provide a more comprehensive dataset for examining the relationship between DOC and CDOM, and the result is very helpful for establishing remote sensing models to estimate DOC through CDOM absorption properties (Cardille et al., 2013; Zhu et al., 2014; Kutser et al., 2015).~~

**[Insert Table 1 about here]**

### 3.2. DOC concentrations in different types of waters

DOC concentrations changed remarkably in the investigated waters (Table 1). DOC concentrations were low in rivers, while they were much lower in ice melting waters sampled in winter~~, which is consistent with previous findings (Bezilie et al., 2002; Shao et al., 2016)~~. It should be noted that large variations were observed in water samples from rivers and streams (Table 2)~~ (Raymond and Saiers, 2010; Ward et al., 2012), due to the strong connection with hydrological condition and catchment landscape features (Neff et al., 2006; Agren et al., 2007; Lee et al., 2015)~~. ~~Generally, low DOC concentrations were found in rivers or streams in the drainage systems in Tibetan Plateau or arid regions in Northwest China where soil contains relative low level of soil organic carbon, but the high DOC concentrations were found in rivers or streams surrounded by forest or wetlands in Northeast China. The similar findings were reported by Agren et al. (2007, 2010). ~~Among the five types of waters, relatively higher DOC concentrations, ranging from 2.3 to 300.6 mg/L, were found in many saline lakes, in the Songnen Plain, the HulunBuir Plateau and some areas in Tibetan Plateau (see Fig.2 for location)~~, which is consistent with previous investigations conducted in the semi-arid or arid regions (Curtis et al., 1995; Song et al., 2013; Wen et al., 2016)~~. However, some of saline lakes supplied by snow melt water or ground water exhibited relatively lower DOC concentrations even with high salinity. Compared with samples collected in growing seasons, higher DOC concentrations (7.3-720 mg/L) were observed in ice-covered water bodies~~, due to the condensed effect caused by the DOC discharged from ice formation (Bezilie et al., 2002; Shao et al., 2016)~~. ~~This condensed effect was particularly marked in these shallow water bodies where ice forming remarkably condensed the DOC in the underlying waters (Zhao et al., 2016a). Even in rivers or~~

~~saline lakes, the concentrations of DOC demonstrated obvious variations (Table 2). Comparatively, rivers from Qinghai exhibited lower DOC concentration, while these from the Liaohe and Inner Mongolia showed much higher DOC concentration (Table 2). Similarly, large DOC variations were observed in saline lakes in different regions (Table 2). Much higher DOC concentrations were found in saline lakes in Qinghai and Hulunbir, while relative low concentrations were observed in Xilinguole Plateau and the Songnen Plain.~~

**[Insert Table 2 about here]**

## 3.3. DOC versus CDOM for various types of waters

### *3.3.1 Freshwater lakes and reservoirs*

The relationship between DOC and CDOM has been ~~researched~~ investigated based on CDOM absorption spectra at different wavelengths (Fichot and Benner, 2011; Spencer et al., 2012; Song et al., 2013; Brezonik et al., 2015). As suggested by Fichot and Benner (2011), CDOM absorptions at 275 nm ($a_{CDOM}(275)$) and 295 nm ($a_{CDOM}(295)$) have stable performances for DOC estimates for coastal waters. In current study, a strong relationship ($R^2 = 0.85$) between DOC and $a_{CDOM}(275)$ was found in fresh lakes and reservoirs (Fig.3a). However, the participation of $a_{CDOM}(295)$ explains very limited variance, thus it is not considered in the regression models. Regression analyses of water samples collected from different regions indicated that the slopes varied from 1.30 to 3.~~13~~ 01 (Table 3). Water samples collected from East China and South China had lower regression slope values (Table 3), and lakes and reservoirs were generally mesotrophic or eutrophic (Huang et al., 2014; Yang et al., ~~2012~~2012, and references therein). ~~Phytoplankton degradation may contribute relative large portion of CDOM and DOC in these water bodies (Zhang et al., 2010), due to the lower molecular weight, its absorption is different from that derived from terrestrial systems (Helms et al., 2008). Comparatively, fresh waters in Northeast and North China revealed larger regression slopes (Table 3).Waters in Northeast China are surrounded by forest, wetlands and grassland and therefore they generally exhibited high proportion of colored fractions, CDOM (Helms et al., 2008). Soils in Northeast China are rich in organic carbon, which may also contribute to high concentration of DOC and CDOM in waters in this region (Jin et al., 2016; Zhao et al., 2016a). Compared with waters in East and South China, waters in Northeast China showed less algal bloom due to low temperature, thus autochthonous CDOM was less presented in waters in Northeast China (Song et al., 2013; Zhao et al., 2016a). As suggested by Brezonik et al. (2015) and Cardille et al. (2013), CDOM in the eutrophic waters or those with very short resident time may show seasonal variation due to algal bloom or hydrological variability, while CDOM in some oligotrhopic lakes or those with long resident time may show an opposite pattern.~~

**[Insert Table 3 about here]**

**[Insert Fig.3 about here]**

### *3.3.2 Saline lakes*

A strong relationship between DOC and $a_{CDOM}(275)$ ($R^2 = 0.85$) was demonstrated for saline lakes (Fig.3b). ~~However, compared to fresh waters, m~~Much lower regression slope value (slope = 1.28) was found in saline lakes. Similar to fresh waters, the slopes of most saline lakes exhibited large variations between different regions (Table 3), ranging from 0.86 in Tibetan waters to 2.83 in the Songnen Plain waters (see Fig.2 for location). As the extreme case, the slope value was only 0.33 as demonstrated in the embedded diagram in Fig.3b. Saline lakes in semi-arid or arid regions generally exhibit higher regression slope values, for example, the west Songnen Plain (2.83), the Hulunbir Plateau and the East Inner Mongolia Plateau (1.79). Whereas, waters in the west Inner Mongolia Plateau (1.13), the Tibetan Plateau (0.86) exhibited low slope values (Table 3), and the extreme low value was measured in the Lake Qinhai in Tibetan Plateau. Lakes in Tarim Basin were affected by strong photo-bleaching, due to the long resident time and strong solar radiation (Spencer et al., 2012; Song et al., 2013; Wen et al., 2016).

~~Thereby, smaller regression slopes were found and less colored portion of DOC was presented in waters in semi-arid to arid regions, especially for these closed lakes with enhanced photochemical processes (Spencer et al., 2012; Song et al., 2013; Wen et al., 2016). The findings highlighted the difference in remote sensing of DOC through CDOM absorption algorithm between saline and fresh lakes, thereby different models should be established to accurately estimate DOC in waters (Cardille et al., 2013; Brezonik et al., 2015).~~

### *3.3.3 Streams and rivers*

Although some of the samples scattered from the regression line (Fig.3c), close relationship between DOC and $a_{CDOM}(275)$ was found for samples collected in rivers and streams. Compared with the other water types (Fig.3), rivers and streams exhibited the highest regression slope value (slope = 3.01~~3~~). Further regression analysis with water samples sub-datasets collected in different regions indicated that slope values presented large variability, ranging from 1.07 to 8.49. The lower regression slope values were recorded in water samples collected in rivers and stream in semi-arid and arid regions, such as the Tibetan Plateau, Mongolia Plateau and Tarim Basin, while the higher values were found in samples collected in streams originated from wetland and forest in Northeast China (Table 3). ~~Rivers and streams in North, East and South China generally exhibited intermediate values. In addition, water samples in large river generally presented relatively low slope value; streams, especially head water originating from forest and wetland dominated regions show higher regression slope values (e.g., Branches from the Nenjiang and the Songhua River in Table 3), which is consistent with the findings from Helm et al. (2008) and Spencer et al. (2012). In fact, landscape pattern and soil organic carbon in the catchment are important factors governing the terrestrial DOC and CDOM characteristics in rivers and streams (Wilson and Xenopoulos, 2008; Jaffe et al., 2008; Agren et al., 2010; Lai et al., 2016).~~

~~DOC concentration is strongly associated with hydrological conditions (Neff et al. 2006; Agren et al. 2007). Thereby, the relationships between CDOM and DOC in river and stream waters are very variable (Lee et al., 2015) due to the hydrological variability and catchment features (Agren et al., 2010; Spencer et al., 2009; 2012).~~ To investigate the dynamics of CDOM absorption and DOC concentrations, three sections were investigated in three major rivers in Northeast China (see Figure S1 for location). River flow exerted obvious effect on DOC and CDOM (Fig.4) and flood impulse brought large amount of DOC and CDOM into river channels~~, which is consistent with previous~~

~~findings (Neff et al., 2006; Larson et al., 2007)~~. ~~As shown in Fig.4, the relationship between river flows and DOC is rather complicated, which is mainly caused by the land use, soil properties, relief, slope, the proportion of wetlands and forest, climate and hydrology of the catchments (Neff et al., 2006; Sobek et al., 2007; Spencer et al., 2012; Zhou et al., 2016), with additional influence by sewage discharge into rivers.~~ The relationships between DOC and $a_{CDOM}(275)$ in sections along three rivers in Northeast China were demonstrated in Fig.5. The sampling point in the Yalu River is near the river head source, thus strong relationship was exhibited with large slope (Fig.5a)~~, due to that the DOC and CDOM were fresh and less disturbed by pollution from anthropogenic activities (Spencer et al., 2012; Shao et al., 2016)~~. The relationship between DOC and $a_{CDOM}(275)$ in the Songhua River at Harbin City section was much scattered (Fig.5c)~~ and this is mainly attributed to both point and non-point source pollution that cause the composition and colored fractions of DOC and DOM much varied comparing to river head waters with less human disturbance. Similar mechanisms are further detailed in section 3.3.4 with urban waters~~. With respect to Fig.5b, it is an in-between case. The sampling point was affected by effluent from Baishan City, thus the coefficient of determination ($R^2$= 0.822) and the regression slope (3.72) were lower than that from the Yalu River at Changbai point, while higher than that from the Songhua River at Harbin point.~~ Thereby, both spatial and temporal changes of the relationships between DOC and CDOM were observed, and anthropogenic activities further complicated the relationship.~~

**[Insert Fig.4 and Fig.5 about here]**

### *3.3.4 Urban waters*

Relative close relationship between DOC and $a_{CDOM}(275)$ was revealed in urban waters (Fig.3d, $R^2$= 0.71)~~, where it was much scattered compared with other water types (Fig.3), particularly for water samples with DOC concentration less than 60 mg/L~~. Similarly, regression slope values changed remarkably, ranging from 0.87 to 2.45. ~~It is apparent that urban waters are severely impacted by human activities, particularly sewage, effluents and runoff from urban impervious surface containing large amount of DOM (Yang et al. 2008; Zhao et al., 2016b, and references therein).~~ High nutrients also usually result in algal bloom in most urban water bodies (Chl-a range: 1.0-521.1μg/L; average: 38.9μg/L). Thereby, DOC and CDOM derived from phytoplankton may also contribute a portion that should not be neglected (~~Xing et al. 2006;~~ Zhang et al., 2010; Zhao et al., 2016b; Zhou et al., 2016). ~~More or less affected by sewage effluent, the DOM in urban waters is much complex than those from natural water bodies. Thus, a large variation of the relationship between DOC and $a_{CDOM}(275)$ was found in urban waters.~~

### *3.3.5 Ice covered lakes and reservoirs*

The closest relationship ($R^2$ = 0.93) between DOC and $a_{CDOM}(275)$ was recorded in waters beneath ice covered lakes and reservoirs in Northeast China (Fig.3e). ~~It was argued that the close relationship indicated the concurrent processes taken place for DOC accumulation and CDOM biogeochemical activities (Finlay et al., 2003; Stedmon et al., 2011). The strong positive correlations between DOC and $a_{CDOM}$275 is probably due to ice formation condensed these two parameters. The other possible explanation~~

~~was that ice and snow cover shielded out most of the solar radiation that might cause a series of biochemical process for CDOM contained in water; further, the inflows and direct rainfall over lakes or reservoirs also diminished, thus causing limited effect on DOC and CDOM composition (Uusikiv et al., 2010; Belzile et al., 2002). Further, the autochthonous DOC and CDOM in ice covered waters were also limited due to the relatively weak primary production in winter (Chl-a = 7.3μg/L), resulting in much close relationship in winter waters.~~

Comparatively, a weak relationship between DOC and $a_{CDOM}(275)$ was demonstrated in ice melting waters (Fig.3f)~~, which was probably due to the ice/water depth ratio causing variation of dissolved components expelled during ice formation. The other reason is the biologically derived DOC in the ice matrix, which changes with the variation of light and nutrient (Arrigo et al., 2010; Zhang et al., 2010)~~. Apparently, CDOM from ice melting waters were mainly originated from maternal water during the ice formation, also from algal biological processes (Stedmon et al., 2011; Arrigo et al., 2010). ~~Similarly, snow cover, and nutrients in the ice also causes the variation of biochemical processes that ultimately complicate the relationship between DOC and CDOM (Bezilie et al., 2002; Spencer et al., 2009).~~ Interestingly, the regression slopes for ice samples (1.35) and under lying water sample (1.27) are very close. In addition, there was a significant relationship between DOC in ice and underlying waters ($R^2$ = 0.86), indicating the dominant components of CDOM and DOC in the ice are from maternal underlying waters.

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### 3.3.6 DOC versus $a_{CDOM}(440)$

CDOM absorption at 440 nm, i.e., $a_{CDOM}(440)$, is usually used as a surrogate to represent its concentration (Bricaud et al., 1981; Babin et al., 2003), and widely used in remote sensing community to quantify CDOM in waters (Lee et al., 2002; Binding et al., 2008; Zhu et al., 2014). Significant relationships between DOC and $a_{CDOM}(440)$ were found in different types of waters (Fig.5). ~~Compared to DOC versus $a_{CDOM}(275)$, the relationships were more scattered due to the weak CDOM absorption at longer wavelength (Bricaud et al., 1981; Binding et al., 2008).~~ Through comparing Fig.3 with Fig.6, it can be found that the overall relationships between DOC and CDOM at 440 nm resembled that at 275 nm for different types of waters. ~~This has important implication for remote sensing of DOC through the CDOM absorption as a bridge (Zhu et al., 2014; Kuster et al., 2015; Brezonik et al., 2015). It is also worth noting that most of the streams and rivers, including some of the urban water bodies, are not suitable to quantify DOC through remote sensing imagery, and this is due to that medium or even coarse resolution imagery cannot effectively capture the change of signals from these small water bodies. However, the systematic examination for the relationship between DOC and CDOM may help to quantify DOC through CDOM absorption for deploying portable sensors in streams or rivers that can measure CDOM absorption more accurately with dynamic manner (Spencer et al., 2012; Lee et al., 2015; Ruhala and Zarnetske, 2016).~~

**[Insert Fig.6 about here]**

### 3.4 CDOM molecular weight and aromacity versus DOC

### 3.4.1 CDOM versus SUVA$_{254}$ and M value ($a_{CDOM}$(250)~~-~~/$a_{CDOM}$(365))

The large slope variations ~~of the slope~~ of regressions ~~of~~between DOC and $a_{CDOM}$(275) in different types of waters are probably due to the aromacity and colored fractions in DOC component (Spencer et al., 2009, 2012; Lee et al., 2015). ~~SUVA$_{254}$ is an effective indicator to characterize CDOM molecular weight~~ As shown in Fig.7a,~~.~~ it can be seen ~~It may reflect the regression slope value between DOC and CDOM absorption at 275 nm. It is obvious~~ that SUVA$_{254}$ had high values in fresh lakes, and waters from rivers or streams as well ~~(Fig.7a)~~. Saline water and ice covered waters in Northeast China showed intermediate SUVA$_{254}$ values, while urban water and ice melting water exhibited lower values. The M value, i.e., $a_{CDOM}$(250)/$a_{CDOM}$ (365) is another indicator to demonstrate the variation of molecular weight ~~and aromacity~~ of CDOM components (De Haan, 1993). Compared to saline waters, ~~F~~fresh lake water (*t-Test*, F = 631, $p < 0.001$), river and stream water (F = 547, $p < 0.001$), and urban water (F = 396, $p < 0.001$) exhibited low M values (Fig.7b), which indicated that large~~r aromacity~~ weight molecules dominate~~dominant~~ ~~for~~in these three types of waters. Saline water, ice covered water in Northeast China and ice melting water showed higher M values. Since SUVA$_{254}$ is a proxy based on the ratio to DOC, it is inappropriate to establish the relationship between CDOM and DOC based on the SUVA$_{254}$ classification. Thereby, only M values, which reveal molecular weight and aromacity, might help to estimate DOC through CDOM absorption based on M ~~threshold~~ values for various types of waters.

**[Insert Fig.7 about here]**

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### *3.4.2 Regression based on M values*

Regression models between DOC and $a_{CDOM}$(275) were established based on M value ~~threshold values~~grouping~~, which were determined through~~ . ~~trial test with respect to the concentrations of DOC versus $a_{CDOM}$(275).~~ Four groups were achieved with hierarchical cluster approach, and each group occupied about 43.48% (M < 8.5), 34.38% (8.5< M < 16.1), 19.35% (16.1< M < 25.6) and 2.79% (25.6< M < 68.0) of the total samples from group 1 to 4, respectively. Though only M values were used in the cluster which meant the feature space in classification only had one dimension and the groups were mainly divided according to the distribution of M values, the hierarchical cluster approach generated rational results. A ~~relative weaker~~ close relationship ($R^2 = 0.92$) between DOC and $a_{CDOM}$(275) was revealed in dataset where M ~~values were less than~~≤ 8.5 (Fig.8a). ~~It should be noted that the high regression slope values appeared in different groups of subset data (Fig.8a-h). The large range of M value (0<M<4.0) may explain the scattered data pairs in Fig.8a and this is also the reason for the group with M values ranging from 4 to 6 (Fig.8b).~~ Likewise, ~~Better~~close relationship regression model~~s~~ appeared in dataset ~~groups~~ with intermediate M values (Fig.8~~c-f~~b)~~, with small range of regression slope values (1.15 – 1.38) and~~, revealing high determination of coefficients ($R^2$ ~~>~~ = 0.~~88~~93). ~~Regression slope values decreased with the increasing of M values (Fig.8g-h).~~ As shown in Fig.8c, a relative ~~W~~weak relationship ($R^2 = 0.75$) between DOC and $a_{CDOM}$(275) appeared with ~~relative lower or higher~~ M values ranging from 16.1 to 25.6~~(Fig.8g)~~. A ~~V~~very ~~significant~~ close relationship ($R^2$ = 0.~~99~~98) was found with extremely high M values (Fig.~~8h~~8d). ~~Most of samples collected from these~~

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~~groups were presented in the embedded diagram in Fig.3b, and the limited water bodies in the group may explain this coincidently high $R^2$ value. With more samples collected from different water bodies in this extreme group, a weak relationship between DOC and $a_{CDOM}$(275) may appear, while future explorations are needed.~~

As noted in Fig.~~8c~~8a-~~f~~c, close regression slopes implicated that a comprehensive regression model with intermediate M values ~~groups~~ less than 16 may be achieved. As expected, a promising regression model (the diagram was not shown) between DOC and $a_{CDOM}$(275)~~$a_{CDOM}$275~~ was achieved ($y = 1.269x + 6.$~~55~~42, $R^2 = 0.$~~925~~909, N = ~~998~~1171, $p < 0.001$) with pooled dataset shown in Figs.8~~c to 8f~~a-b. Inspired by this idea, the relationship between $a_{CDOM}$(275) and DOC also examined with pooled data. As shown in Fig.9a, a significant relationship between DOC and $a_{CDOM}$(275) was obtained with the pooled dataset (N = 1504) collected from different types of inland waters. However, it should be noted that the extremely high DOC samples may advantageously contribute the better performance of the regression model. Thus, regression model excluding these eight samples (DOC > 300 mg/L) was still ~~significant~~ acceptable (Fig.9b, $R^2 = 0.66$, $p < 0.001$). In addition, regression model with power function– was established in~~based on~~ decimal logarithms ~~transformed data~~log-log scale ~~was established~~ (Fig.9c, $R^2 = 0.$~~82~~95, $p < 0.001$). ~~Most of the paired data sitting close to the regression line except some scattered ones. This also implies that relative accurate regression model for CDOM versus DOC can be achieved with data collected in inland waters at global scale (Sobek et al., 2007), which might be helpful in quantifying DOC through linking with CDOM absorption spectra, and the latter parameter can be~~

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~~estimated from remote sensing data (Zhu et al., 2011; Kuster et al., 2015).~~

**[Insert Fig.8 and Fig.9 about here]**

# 4. Discussion

## 4.1 Variation of water quality parameters

Different water types were sampled across China with different climatic, hydrologic, and land use conditions in various catchment, combined with different anthropogenic intensity, thus ~~T~~the ~~he~~ biological and geochemical properties in the water bodies are quite diverse with large range values for each parameters (Table 1). Extremely turbid waters are observed for fresh waters, saline waters and underlying waters covered by ice~~ in Northeast China (see TSM values in Table 1)~~, which were generally collected in very shallow water bodies in different parts of China. As expected, large variations of Chl-a are observed for both fresh waters and urban waters, and particularly these samples collected in urban waters show large range (1.0-521.1 μg/L). Our investigation also indicates that algal growth is still very active in these ice covered water bodies in Northeast China, which might result from high TN (4.3±5.4mg/L) and TP (0.7±0.6mg/L) concentrations in these waters bodies. It also should be noted that DOC, EC and pH were high in semi-arid or arid climatic regions, which are consistent with previous findings (Curtis ~~et al~~and Adams~~.~~, 199~~7~~5; Song et al., 2013; Wen et al., 2016).

## 4.2 DOC variation with different types of waters

This investigation indicates that lower DOC were encountered with samples collected in rivers from the Tibetan Plateau (Table 2), where the average soil organic matter is

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lower, thus terrestrial DOC input from the catchment is less (Tian et al., 2008). Generally, low DOC concentrations were found in rivers or streams in the drainage systems in Tibetan Plateau or arid regions in Northwest China where soil contains relative low level of soil organic carbon, but the high DOC concentrations were found in rivers or streams surrounded by forest or wetlands in Northeast China, the similar findings were also reported by Agren et al. (2007, 201~~0~~1). Further, lower DOC concentration is also measured with ice samples, which is consistent with previous findings (Bezilie et al., 2002; Shao et al., 2016). But relatively high DOC concentration was observed for underlying waters covered by ice in Northeast China due to the condensed effect caused by the DOC discharged from ice formation (Bezilie et al., 2002; Shao et al., 2016; Zhao et al., 2016a). This condensed effect was particularly marked in these shallow water bodies where ice forming remarkably condensed the DOC in the underlying waters (Zhao et al., 2016a). It also should be noted that DOC concentration has a strong connection with hydrological condition and catchment landscape features (Neff et al., 2006; Agren et al., 2007; Lee et al., 2015).~~ As shown in Table 2, the concentrations of DOC demonstrated obvious variations even in rivers or saline lakes. Comparatively, rivers from Qinghai exhibited lower DOC concentration, while these from the Liaohe and Inner Mongolia showed much higher DOC concentration (Table 2). ~~Similarly, large DOC variations were observed in saline lakes in different regions (Table 2). Much higher DOC concentrations were found in saline lakes in Qinghai and Hulunbir, while relative low concentrations were observed in Xilinguole Plateau and the Songnen Plain, which is consistent with previous investigations conducted in the semi-arid or arid regions (Curtis ~~et al.~~and Adams, 1995; Song et al., 2013; Wen et al., 2016).

### 4.3 Variation of the relationships between CDOM and DOC

As demonstrated in Fig.3, obvious variation is revealed for the regression slope values between DOC and $a_{CDOM}$(275). Most of the fresh water bodies are located in East China, where agricultural pollution and anthropogenic discharge have resulted in serious eutrophication (Tong et al., 2017). Phytoplankton degradation may contribute relative large portion of CDOM and DOC in these water bodies (Zhang et al., 2010; Zhou et al., 2016). Comparatively, fresh waters in Northeast and North China revealed larger regression slopes (Table 3). Waters in Northeast China are surrounded by forest, wetlands and grassland and therefore they generally exhibited high proportion of colored fractions of DOC. Further, soils in Northeast China are rich in organic carbon, which may also contribute to high concentration of DOC and CDOM in waters in this region (Jin et al., 2016; Zhao et al., 2016a). Compared with waters in East and South China, waters in Northeast China showed less algal bloom due to low temperature, thus autochthonous CDOM was less presented in waters in Northeast China (Song et al., 2013; Zhao et al., 2016a). As suggested by Brezonik et al. (2015) and Cardille et al. (2013), CDOM in the eutrophic waters or those with very short resident time may show seasonal variation due to algal bloom or hydrological variability, while CDOM in some oligotrophic lakes or those with long resident time may show ~~an opposite~~a stable pattern.

As shown in Fig.3b, smaller regression slope~~s~~ ~~are~~is revealed between DOC and $a_{CDOM}$(275)~~CDOM and DOC~~ for saline waters, indicating less colored portion of DOC

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was presented in waters in semi-arid to arid regions, especially for these closed lakes with enhanced photochemical processes (Spencer et al., 2012; Song et al., 2013; Wen et al., 2016). The findings highlighted the difference for the relationship between CDOM and DOC, thus different regression models should be established to accurately estimate DOC in waters through linking with CDOM absorption, particularly for fresh and saline waters that showing different specific absorption coefficients (Song et al., 2013; Cardille et al., 2013; Brezonik et al., 2015).

The current study indicates that CDOM from river and stream waters show higher absorption coefficient, and larger regression ~~coefficients~~slope ~~were~~is revealed (Fig.3c). However, obvious variation for the regression slopes is demonstrated for samples collected in different part of the country (Table 3), which is consistent with the findings from Spencer et al. (2012) and ~~(~~Zhao et al.~~,~~ (2017). Rivers and streams in North, East and South China generally exhibited intermediate values. In addition, water samples in large river generally presents relatively low slope value; streams, especially head water originating from forest and wetland dominated regions show higher regression slope values (e.g., Branches from the Nenjiang and the Songhua River in Table 3), which is consistent with the findings from Spencer et al. (2012). In fact, landscape pattern and soil organic carbon in the catchment are important factors governing the terrestrial DOC and CDOM characteristics in rivers and streams (Wilson and Xenopoulos, 2008; Jaffe et al., 2008; Agren et al., 201~~0~~1; Lai et al., 2016; Zhao et al., 2017).

DOC concentration is strongly associated with hydrological conditions (Neff et al. 2006; Agren et al. 2007; Yu et al., 2016). The relationships between CDOM and DOC in river and stream waters are very variable ~~(Lee et al., 2015)~~ due to the hydrological variability and catchment features (~~Worral et al., 2006;~~ Agren et al., 201~~0~~1; Spencer et al., 2009; 2012; Ward et al., 2013; Lee et al., 2015).

As shown in Fig.4, the relationship between river flows and DOC is rather complicated, which is mainly caused by the land use, soil properties, relief, slope, the proportion of wetlands and forest, climate and hydrology of the catchments (Neff et al., 2006; Sobek et al., 2007; Spencer et al., 2012~~,~~; Zhou et al., 2016), with additional influence by sewage discharge into rivers. For head waters, close relationship between CDOM and DOC is revealed with higher regression slope value (Fig.5a), which is mainly because that the DOC and CDOM were fresh and less disturbed by pollution from anthropogenic activities (Spencer et al., 2012; Shao et al., 2016). Comparatively, loose relationship was revealed for rivers with both point and non-point source pollution that cause the composition and colored fractions of DOC and DOM much varied (Fig.5c). Thereby, both spatial and temporal changes of the relationships between DOC and CDOM were observed, and anthropogenic activities further complicated the relationship.

## 4.4 Regression models based on CDOM grouping

As observed in Fig.3, the regression slopes (range: 0.33~3.01) for the relationship between DOC and $a_{CDOM}(275)$ varied significantly. The CDOM absorption coefficient is affected by its components and aromacity, thus the M values are used to classify CDOM into different groups, which turns to be an effective approach for improving regression model between DOC and $a_{CDOM}(275)$.~~Most of samples collected from these~~

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~~groups were presented in the embedded diagram in Fig.3b, and the limited water bodies in the group may explain this coincidentally high $R^2$ value.~~ Most of the paired data sitting close to the regression line except some scattered ones (Fig. 8a-b). It also should be highlighted that the fourth group is mainly from saline lakes (samples from embedded diagram in Fig.3b), thus the regression model slope is extremely low. From the regression model with pooled data, it can also be seen ~~With more samples collected from different water bodies in this extreme group, a weak relationship between DOC and $a_{CDOM}$(275) may appear, while future explorations are needed. Most of the paired data sitting close to the regression line except some scattered ones. This also implies~~ that relative accurate regression model for CDOM versus DOC can be achieved with data collected in inland waters at global scale (Sobek et al., 2007), which might be helpful in quantifying DOC through linking with CDOM absorption spectra, and the latter parameter can be estimated from remote sensing data (Zhu et al., 2011; Kuster et al., 2015).

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# ~~4~~5. Conclusions

~~As a powerful technology, remote sensing plays a crucial role in assessing CDOM and DOC in water environment. In order to get accurate estimates of CDOM and DOC in waters, it is necessary to get insight into the regional water optical properties for developing semi-analytical or analytical models with remotely sensed data.~~ Based on the measurement of CDOM absorption spectra~~l~~ and DOC laboratory analysis, we have systematically examined the relationships between CDOM and DOC in various types of waters in China. This investigation showed that CDOM absorption varied significantly. River waters and fresh lake waters exhibited high CDOM absorption values and specific CDOM absorption ($SUVA_{254}$). On the contrast, saline lakes illustrated low $SUVA_{254}$ values due to the long residence time and strong photo-bleaching effects on waters in the semi-arid regions. Influenced by effluents and sewage waters, CDOM from urban water bodies showed much complex absorption ~~feature~~characteristics. ~~$SUVA_{254}$ for CDOM was lowest in ice melting water samples.~~

The current investigation indicated that the relationships between CDOM absorption and DOC varied remarkably by showing very varied regression slopes ~~values of regression models~~ in various types of waters.~~ The slope values of saline lakes and urban waters were close to unity, slope values of river water were highest (~ 3.1), and slope values of other water types were in between.~~ ~~It should also be highlighted that h~~Head river water generally exhibits larger regression slope values, while rivers affected by anthropogenic activities show lower slope values. Saline water generally reveals small regression slope due to the photobleaching effect in the semi-arid or arid region, combined with longer residence time.~~When all the data set were pooled together, the slope for regression model was about 1.3, but with much bigger uncertainty ($R^2$ = 0.66).~~ The accuracy of regression model between $a_{CDOM}(275)$ and DOC was improved when CDOM absorptions were divided into different sub-groups according to M values. Our finding highlights that remote sensing models for DOC estimation based on the relationship between CDOM and DOC should consider water types or cluster waters into several groups according to their absorption features.~~ More researches are still needed to further improved model accuracy.~~

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**带格式的:** 首行缩进: -2 字符

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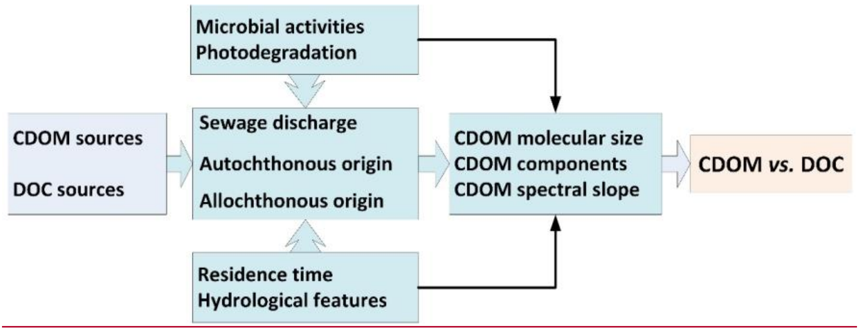
## Figures

Fig.1. ~~the~~ The ~~diagram shows the~~potential regulating factors that influence the relationship between CDOM and DOC. Note, hydrological feature includes flow discharge, drainage area, catchment landscape, river level, and inflow or outflow regions.



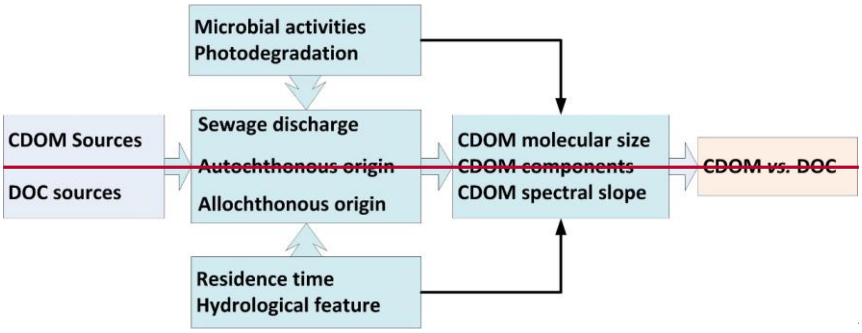


Fig.2. Water types and sample distributions across the mainland China. The dash line shows the boundary of some typical geographic units (i.e., Tibet Plateau, Songnen Plain, and Hulun Buir Plateau).

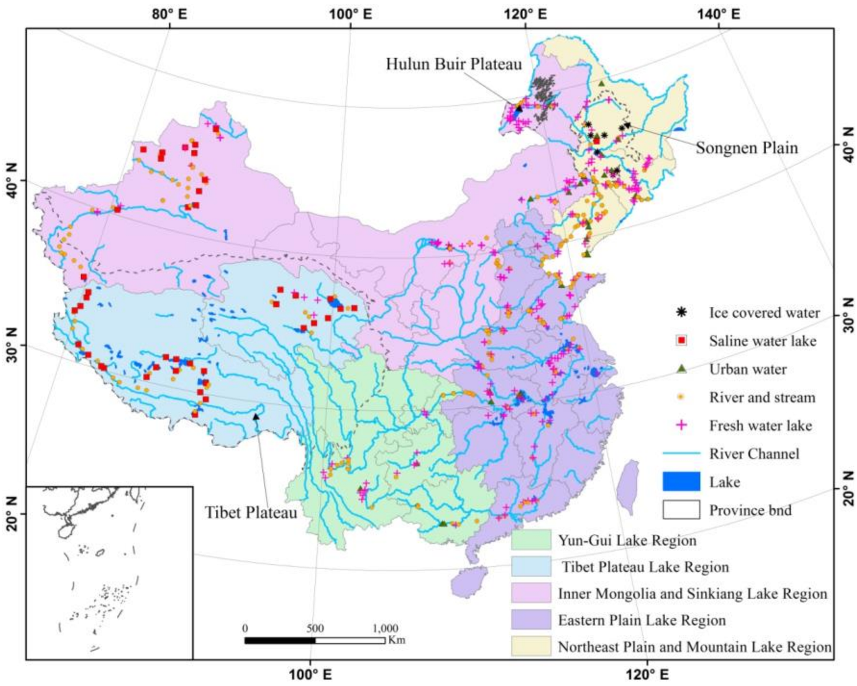
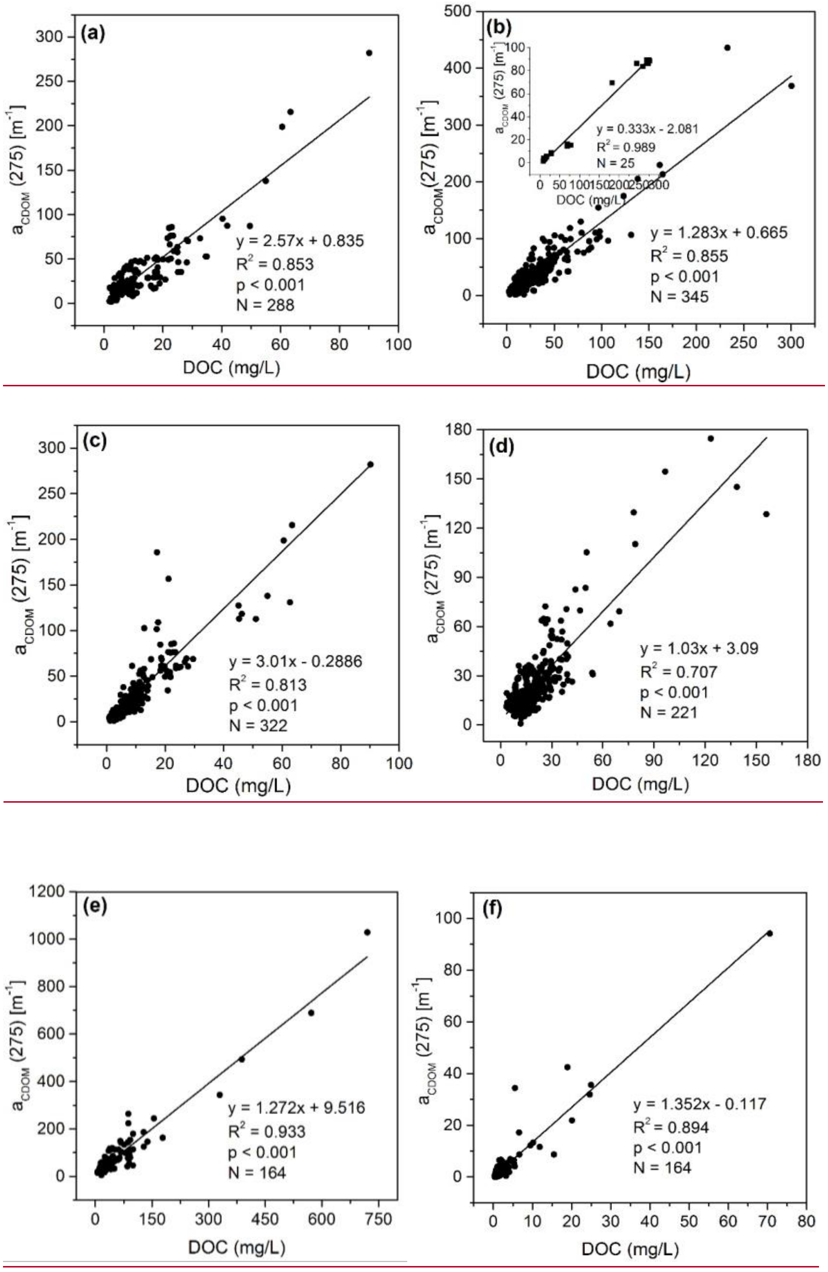


Fig.3. Relationship between DOC and $a_{CDOM}(275)$ in different types of inland waters, (a) fresh water lakes, (b) saline water lakes, (c) river and stream waters, (d) urban waters, (e) ice covered lake underlying waters, and (f) ice melting lake waters.



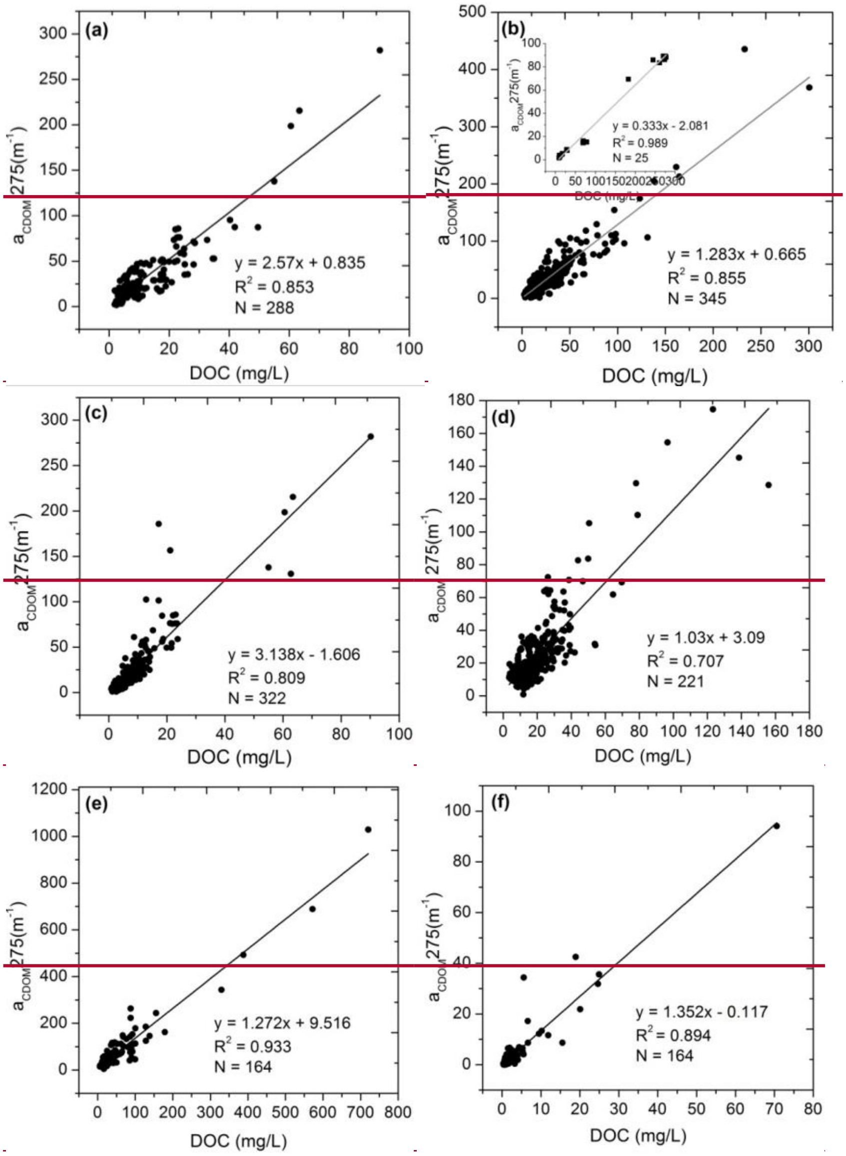
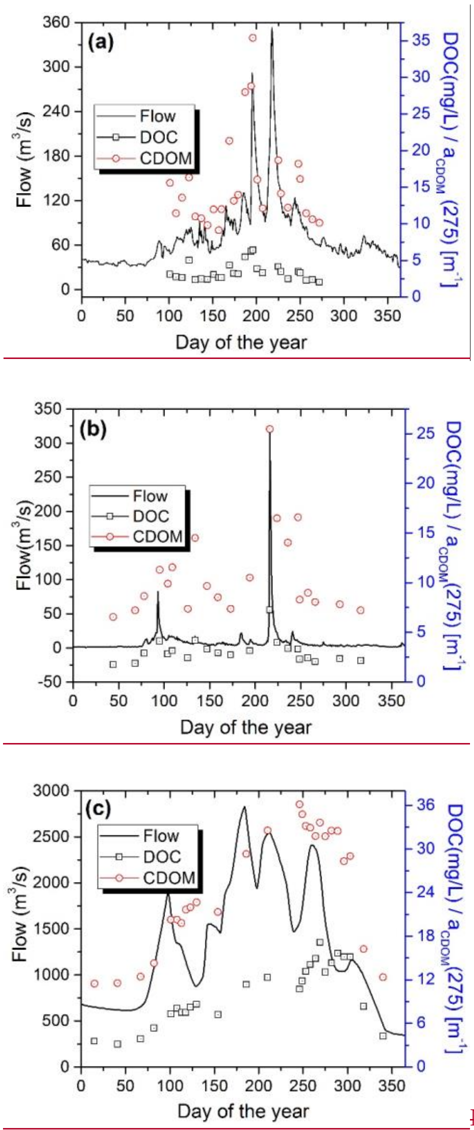

(a)
a_CDOM275(m^-1)
DOC (mg/L)
y = 2.57x + 0.835
R^2 = 0.853
N = 288
0
50
100
150
200
250
300
0
20
40
60
80
100
(b)
a_CDOM275(m^-1)
DOC (mg/L)
y = 1.283x + 0.665
R^2 = 0.855
N = 345
0
100
200
300
400
500
0
50
100
150
200
250
300
y = 0.333x - 2.081
R^2 = 0.989
N = 25
(c)
a_CDOM275(m^-1)
DOC (mg/L)
y = 3.138x - 1.606
R^2 = 0.809
N = 322
(d)
a_CDOM275(m^-1)
DOC (mg/L)
y = 1.03x + 3.09
R^2 = 0.707
N = 221
0
20
40
60
80
100
120
140
160
180
(e)
a_CDOM275(m^-1)
DOC (mg/L)
y = 1.272x + 9.516
R^2 = 0.933
N = 164
0
200
400
600
800
1000
1200
0
100
200
300
400
500
600
700
800
(f)
a_CDOM275(m^-1)
DOC (mg/L)
y = 1.352x - 0.117
R^2 = 0.894
N = 164
0
20
40
60
80
100
0
10
20
30
40
50
60
70
80

Fig.4. Concurrent ~~F~~flow dynamics for three rivers in Northeast China and the corresponding DOC and CDOM variations in 2015; (a) the Yalu River near Changbai County, (b) the Hunjiang River with DOC and CDOM sampled at Baishan City, while the river flow gauge station is near the Tonghua City, (c) the Songhua River at Harbin City.



~~Note, the flow data for the Yalu River and the Hunjiang River were the average values measured during 1970s, while the~~

~~Songhua River was measured during 2000-2010.~~

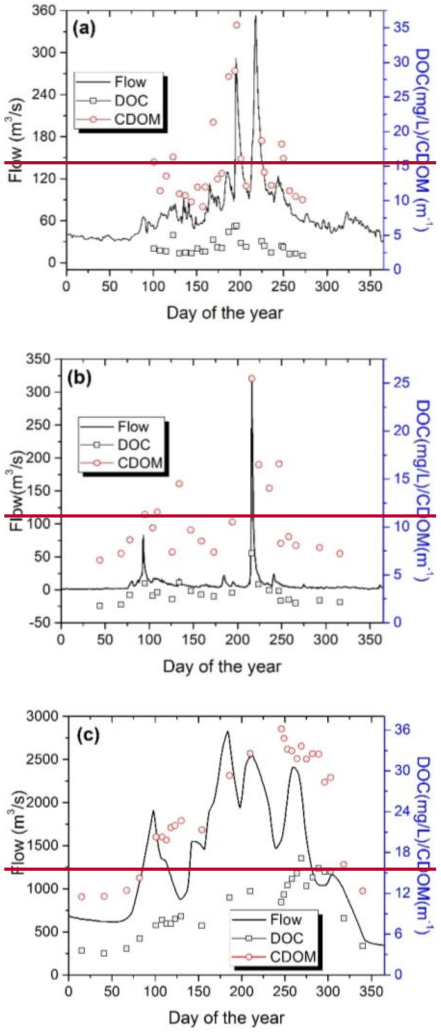


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Fig.5. The relationships between $a_{CDOM}$(275) and DOC at sections across (a) the Yalu River, (b) the Hunjiang River, and (c) the Songhua River. The samples were collected at each station at about one week or around ten days in ice free season in 2015.

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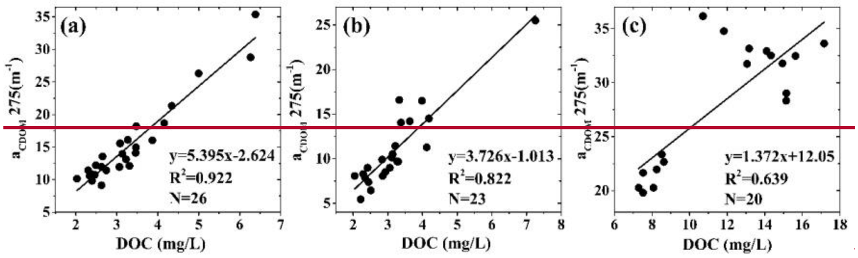


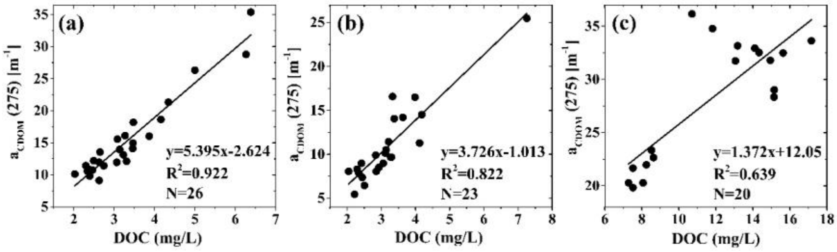
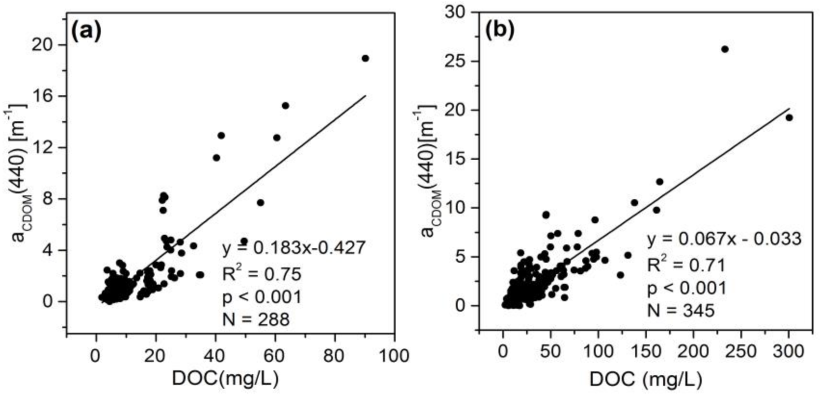
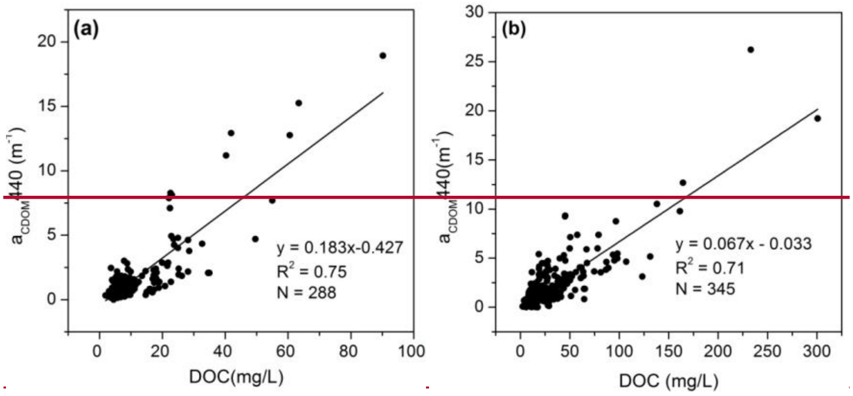
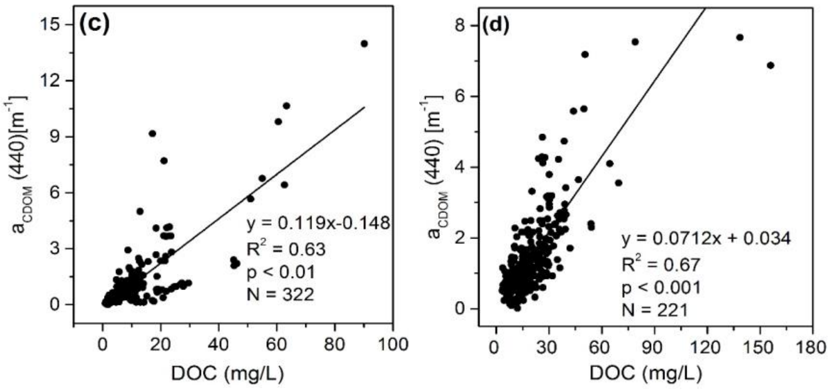
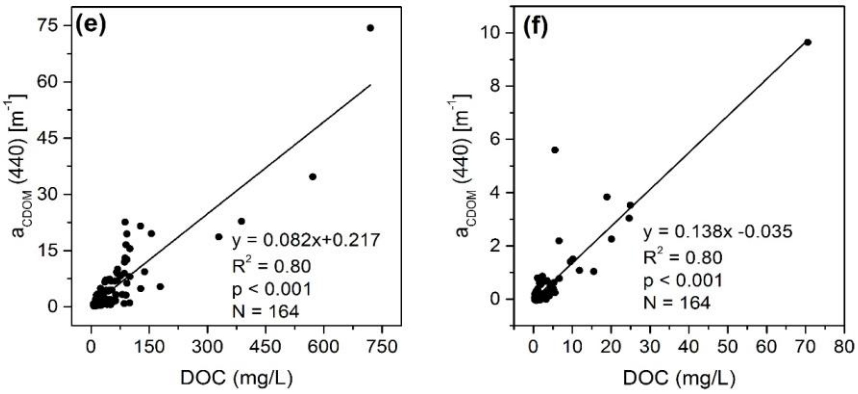


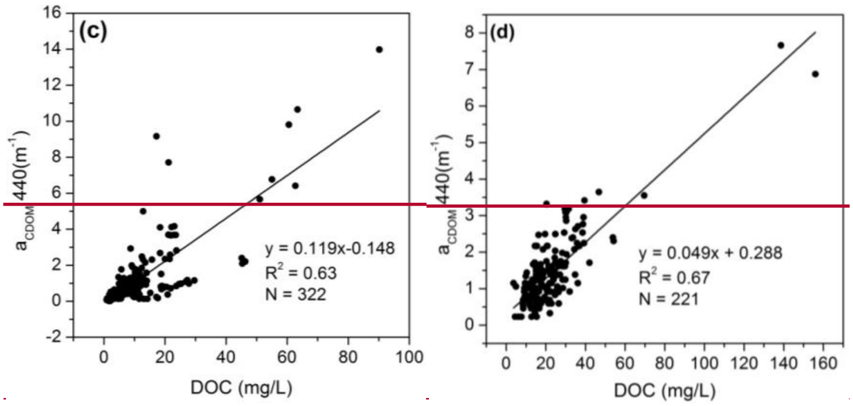
Fig.6. Relationship between DOC and $a_{CDOM}(440)$ in different types of inland waters, (a) fresh water lakes, (b) saline water lakes, (c) river and stream waters, (d) urban waters, (e) ice covered lake underlying waters, and (f) ice melting waters.








(e)
a_CDOM (440) [m^-1]
y = 0.082x+0.217
R^2 = 0.80
p < 0.001
N = 164
DOC (mg/L)
0 150 300 450 600 750
0 15 30 45 60 75
(f)
a_CDOM (440) [m^-1]
y = 0.138x -0.035
R^2 = 0.80
p < 0.001
N = 164
DOC (mg/L)
0 10 20 30 40 50 60 70 80
0 2 4 6 8 10


(c)
a_CDOM 440(m^-1)
y = 0.119x-0.148
R^2 = 0.63
N = 322
DOC (mg/L)
0 20 40 60 80 100
-2 0 2 4 6 8 10 12 14 16
(d)
a_CDOM 440(m^-1)
y = 0.049x + 0.288
R^2 = 0.67
N = 221
DOC (mg/L)
0 20 40 60 80 100 120 140 160
0 1 2 3 4 5 6 7 8

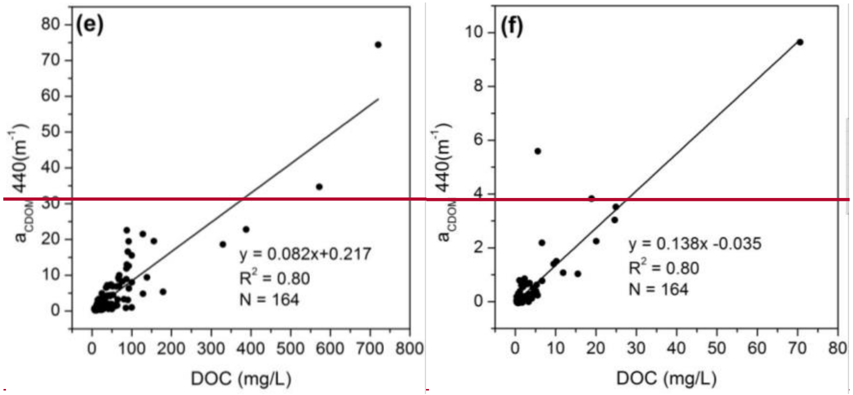

(e)
a_CDOM 440(m^-1)
y = 0.082x+0.217
R^2 = 0.80
N = 164
DOC (mg/L)
0 100 200 300 400 500 600 700 800
0 10 20 30 40 50 60 70 80
(f)
a_CDOM 440(m^-1)
y = 0.138x -0.035
R^2 = 0.80
N = 164
DOC (mg/L)
0 10 20 30 40 50 60 70 80
0 2 4 6 8 10

Fig.7. Comparison of (a) SUVA$_{254}$, and (b) M values (a$_{CDOM}$(250) / a$_{CDOM}$(365)) ~~($a_{250}$:$a_{365}$) values~~ in various types of inland waters. FW, fresh lake water; SW, saline lake water, RW, river or stream water; UW, urban water; WW, ice covered ~~winter~~ waters from Northeast China; IMW, ice melt waters from Northeast China.

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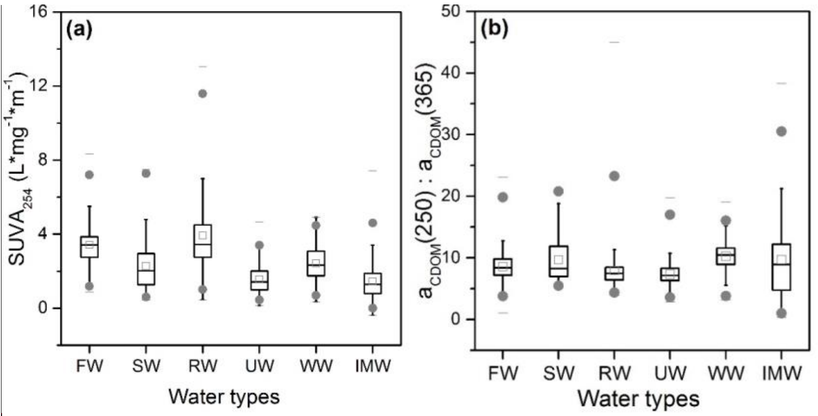


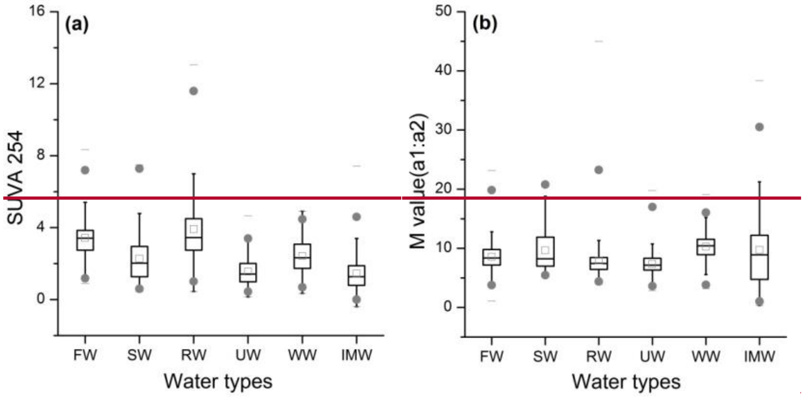
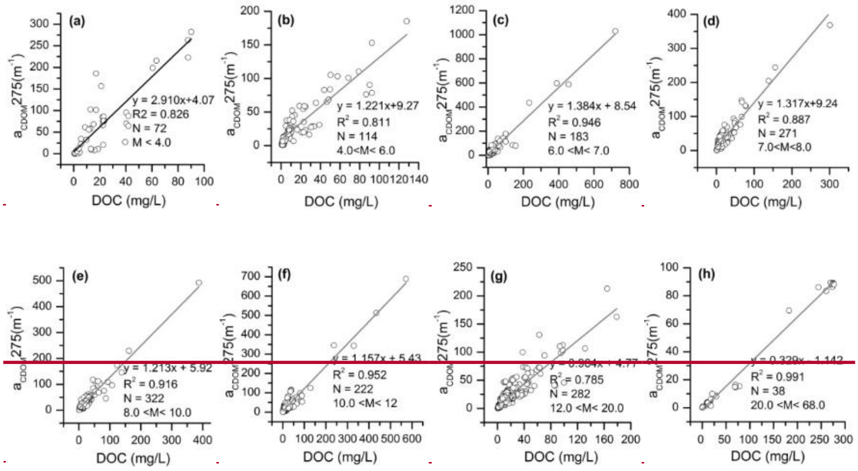
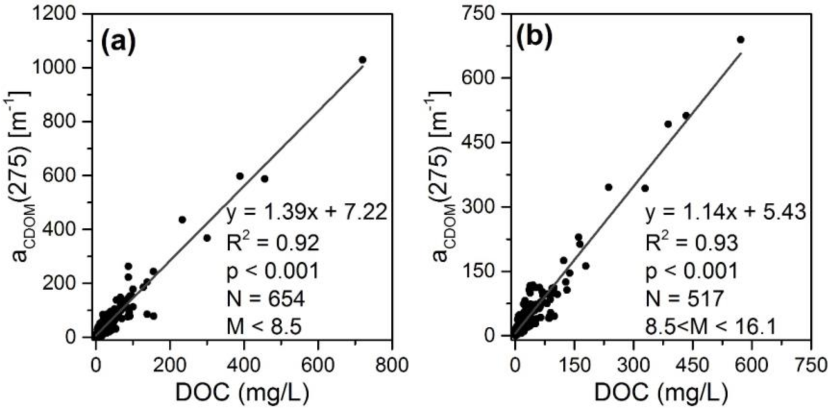


Fig.8. Relationship between DOC and $a_{CDOM}275$ sorted by M ($a_{CDOM}(250)/a_{CDOM}(365)$) values~~ ranges~~, (a) M <~~4~~8.~~0~~5, (b) ~~4~~8.~~0~~5< M<16.~~0~~1, (c) 16.~~0~~1< M< ~~7~~25.~~0~~6, and (d) ~~7.0< M< 8.0, (e) 8.0< M< 10.0, (f) 10.0< M< 12.0, (g) 12.0< M< 20.0, and (h) ~~2~~0~~5.~~0~~6< M< 68.0.





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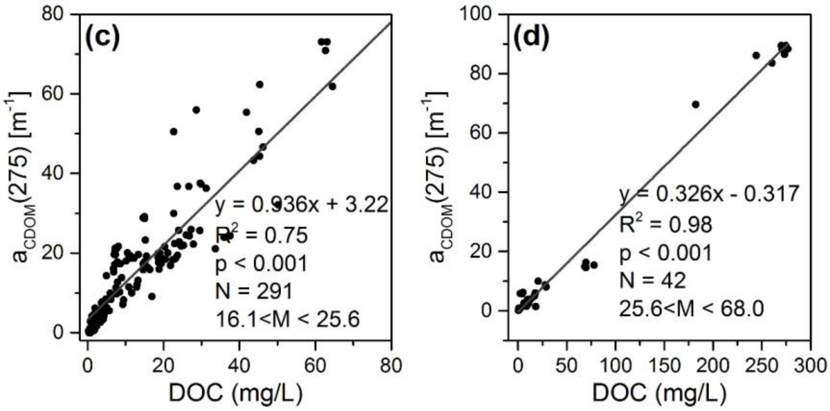
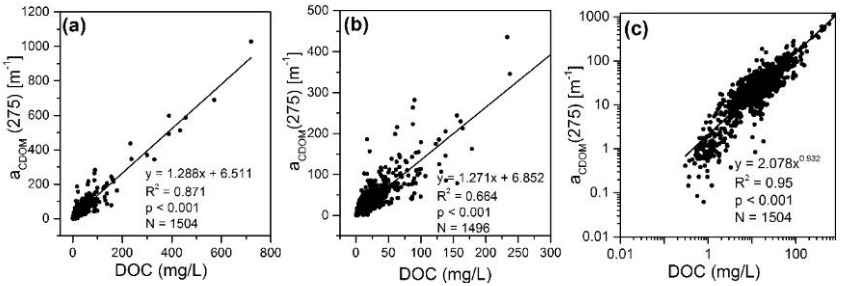
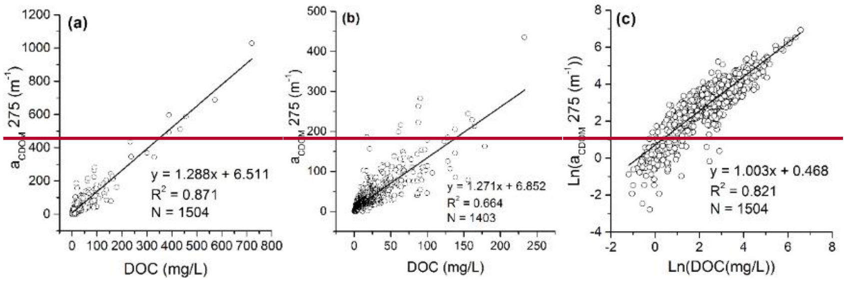

(c)
80
60
40
20
0
0
20
40
60
80
$a_{CDOM}(275)$ [m$^{-1}$]
DOC (mg/L)
y = 0.936x + 3.22
$R^2$ = 0.75
p < 0.001
N = 291
16.1<M < 25.6
(d)
100
80
60
40
20
0
0
50
100
150
200
250
300
$a_{CDOM}(275)$ [m$^{-1}$]
DOC (mg/L)
y = 0.326x - 0.317
$R^2$ = 0.98
p < 0.001
N = 42
25.6<M < 68.0

Fig.9. the relationships between $a_{CDOM}$(275) and DOC concentrations. (a) regression model with pooled dataset; (b) regression model with DOC concentration less than 300 mg/L; (c) regression model with power fitting function based on ~~natural logarithmic transformed~~log-log scale~~ data~~.





## Tables

Table 1. Water quality in different types of waters, DOC, dissolved organic carbon; EC, electrical conductivity; TP, total phosphorus; TN, total nitrogen; TSM, total suspended matter; Chl-a, chlorophyll-a concentration.

| | | DOC (mg/L) | EC μs/cm | pH | TP (mg/L) | TN (mg/L) | TSM (mg/L) | Chl-a (μg/L) |
|---|---|---|---|---|---|---|---|---|
| FW | Mean | 10.2 | 434.0 | 8.2 | 0.5 | 1.6 | 67.8 | 78.5 |
| | Range | 1.9-90.2 | 72.7-1181.5 | 6.9-9.3 | 0.01-10.4 | 0.001-9.5 | 0-1615 | 1.4-338.5 |
| SW | Mean | 27.3 | 4109.4 | 8.6 | 0.4 | 1.4 | 115.7 | 9.0 |
| | Range | 2.3-300.6 | 1067-41000 | 7.1-11.4 | 0.01-6.3 | 0.6-11.0 | 1.4-2188 | 0-113.7 |
| RW | Mean | 8.3 | 10489.1 | 7.8-9.5 | - | - | - | - |
| | Range | 0.9-90.2 | 3.7-1000 | 8.6 | - | - | - | - |
| UW | Mean | 19.44 | 525.4 | 8.0 | 3.4 | 3.5 | 50.5 | 38.9 |
| | Range | 3.5-123.3 | 28.6-1525 | 6.4-9.2 | 0.03-32.4 | 0.04-41.9 | 1-688 | 1.0-521.1 |
| WW | Mean | 67.0 | 1387.6 | 8.1 | 0.7 | 4.3 | 181.5 | 7.3 |
| | Range | 7.3-720 | 139-15080 | 7.0-9.7 | 0.1-4.8 | 0.5-48 | 9.0-2174 | 1.0-159.4 |
| IMW | Mean | 6.7 | 242.8 | 8.3 | 0.19 | 1.1 | 17.4 | 1.1 |
| | Range | 0.3-76.5 | 1.5-4350 | 6.7-10 | 0.02-2.9 | 0.3-8.6 | 0.3-254.6 | 0.28-5.8 |

Note: FW, fresh water lake; SW, saline water lake, RW, river or stream water; UW, urban water; WW, ice covered winter water from Northeast China; IMW, ice melt water from Northeast China.

Table 2. Descriptive statistics of dissolved organic carbon (DOC) and $a_{\mathrm{CDOM}}(440)$ in various types of waters.

| Type | Region | DOC (mg/L) | | | | $a_{\mathrm{CDOM}}(440)$ [m$^{-1}$] | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Min | Max | Mean | S.D | Min | Max | Mean | S.D |
| River | Liaohe | 3.6 | 48.2 | 14.3 | 9.49 | 0.46 | 3.68 | 0.92 | 0.58 |
| | Qinghai | 1.2 | 8.5 | 4.4 | 1.96 | 0.13 | 2.11 | 0.54 | 0.63 |
| | Inner Mongolia | 16.9 | 90.2 | 40.4 | 24.84 | 0.32 | 7.46 | 1.03 | 2.11 |
| | Songhua | 0.9 | 21.1 | 8.1 | 4.96 | 0.32 | 18.93 | 3.2 | 4.19 |
| Saline | Qinghai | 1.7 | 130.9 | 67.9 | 56.7 | 0.13 | 0.86 | 0.36 | 0.23 |
| | Hulunbir | 8.4 | 300.6 | 68.5 | 69.2 | 0.82 | 26.21 | 4.41 | 4.45 |
| | Xilinguole | 3.74 | 45.4 | 14.2 | 8.8 | 0.36 | 4.7 | 1.34 | 0.88 |
| | Songnen | 3.6 | 32.6 | 16.4 | 7.4 | 0.46 | 33.80 | 2.4 | 3.78 |

Table 3. Fitting equations for DOC against $a_{CDOM}(275)$ in different types of waters except ice covered lake underlying water and ice melting waters.

| Water types | Region or Basin | Equations | $R^2$ | N |
|---|---|---|---|---|
| Freshwater lakes | Northeast Lake Zone | y = 3.13x-3.438 | 0.87 | 102 |
| | North Lake Zone | y = 2.16x-1.279 | 0.90 | 63 |
| | East Lake Zone | y = 1.98x+7.813 | 0.66 | 69 |
| | Yungui Lake Zone | y = 1.295x-44.56 | 0.71 | 54 |
| Saline lakes | Songnen Plain | y = 2.383x+1.101 | 0.92 | 159 |
| | East Mongolia | y = 1.791x+8.560 | 0.67 | 57 |
| | West Mongolia | y = 1.133x+3.900 | 0.81 | 46 |
| | Tibetan Plateau | y = 0.864x+2.255 | 0.84 | 83 |
| Rivers or streams | Branch of the Nenjiang River | y = 7.655x-42.64 | 0.81 | 33 |
| | Songhua River stem | y = 3.759x-6.618 | 0.71 | 29 |
| | Branch of Songhua River | y = 8.496x-12.14 | 0.98 | 33 |
| | Liao River Autumn 2012 | y = 1.099x+3.900 | 0.80 | 38 |
| | Liao River Autumn 2013 | y = 1.073x-4.157 | 0.88 | 28 |
| | Liao River Spring 2013 | y = 2.262x-10.32 | 0.85 | 25 |
| | Rivers from North China | y = 3.154x-1.207 | 0.87 | 48 |
| | Rivers from East China | y = 3.037x-2.585 | 0.88 | 47 |
| | Rivers from Tibetan | y = 2.345x+2.375 | 0.87 | 41 |
| Urban waters | Waters from Changchun | y = 2.471x-2.231 | 0.54 | 48 |
| | Waters from Harbin | y = 1.413x-4.521 | 0.67 | 31 |
| | Waters from Beijing | y = 0.874x+11.12 | 0.63 | 27 |
| | Waters from Tianjin | y = 0.994x + 7.368 | 0.57 | 23 |

**8/16/2017**

**Dear Professor C. Stamm,**

Enclosed is the revised manuscript with reference number of “hess-2017-179”. Please accept it as a candidate for publication in **Hydrology and Earth System Science**.

As suggested by two of the three reviewers, we separated the results and discussion into two sections, and thus some of the parts are rewritten in the revised manuscript. Each of the reviewers’ comment or suggestion was incorporated in the revised manuscript, and responses were provided in the previous replies. Further, the regression models based on M value grouping were also reestablished, and the grouping method based on the hierarchical cluster approach was also provided in the revised manuscript. Some of the diagrams were reproduced in the revised manuscript, thus the integrity of these figures was achieved with better presentation. We thank you and the three referees for the valuable comments and suggestions that really improved our manuscript.

Sincerely,

**Dr. Kaishan Song**

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**Phone:** 86-431-85542364; **E-mail address:** songks@iga.ac.cn

## Responses to editor’s comment

HESSD-Manuscript “A systematic examination of the relationships between CDOM and DOC in inland waters in China” (HESS 2017-179).

Dear Dr. K. Song

Reading through the manuscript, I came across a number of aspects on which I’d like to comment on during this discussion phase.

Comments on content:

L.70-75: Provide explanations on mechanisms how hydrology affects DOC and CDOM properties. Why shall catchment size per se be important? Can you explain why size is influential apart from affecting for example travel times?

**Response:** The authors really thank for your thoughtful comments. To my knowledge, these hydrological factors may influence DOC and CDOM properties, 1) the source of DOC and CDOM drain to rivers from the catchment, thus the landscape and the soil organic density influence DOC and CDOM abundance in the rivers; 2) the hydrograph is another factor influences DOC concentration in rivers, generally before peak flow the river shows relatively lower DOC, but relatively higher DOC exhibits after the peak flow due to more DOC release from soil; 3) generally small river catchment tends to have homogeneous landscape, and DOC and CDOM easily drain to river without too much change during this draining processes, that explains why head water generally exhibit higher DOC and CDOM, also more close relationship reveals for DOC and CDOM in head waters; in terms of larger catchment, larger variability for landscape, soil properties will exhibit, longer travel time takes place (photo-degradation and microbial degradation reduce the colored fraction of DOC, and also DOC will mineralize), which ultimately affect the CDOM and DOC properties. Also, rivers in tropical or subtropical regions tend to show lower DOC, which is mainly due to the higher frequency of flushing dilutes the DOC in rivers; comparatively, less rainfall produce less surface flow in temperature regions, where higher DOC generally exhibit in rivers in these region, of course relatively higher soil organic matter also contributes the higher DOC and CDOM in temperature rivers.

L.316: If you know about these influencing factors, why you cannot derive an explanatory model for the slope?

**Response:** Thanks for your comments, but I am not sure I fully understand your comments. We roughly know these influencing factors, however, the variation caused by each factors and the contribution to the total variation by each factor are not clear, and also these factors are intermingled or interacted each other, thus it is very hard to establish an explanatory model for the slope. In addition, the relationship between DOC and CDOM for different waters varies substantially due to the compositional differences for CDOM, and the fraction of colored components in DOC is changeable, which ultimately influences the relationship between DOC and CDOM, thus only a relative stable regression model is achievable for a specific types of waters, not possible for all types of waters. I am not sure if I have answered your question.

L.345-347: Again, you should explain how hydrology and catchment characteristics can influence CDOM and DOC.

**Response:** Thanks for your valuable comments. Most of the explanation was presented in the responses above. Further, I would highlight that rivers in arid or semi-arid regions (through our work and also work by Spencer et al. (2012, JGR)) generally exhibit higher DOC concentration, but the absorption coefficient for CDOM is generally low with higher spectral slope, in which the high concentration of DOC is caused by the condensed effect through evaporation; as for the deep spectral slope, the longer traveling time, strong dose of irradiance with less cloud cover, can be attributed for this phenomenon.

L.350-357, Fig. 4: This part is highly misleading because the text evokes the impression that you compare DOC and CDOM to simultaneous measurements of discharge.

Unfortunately, this is not the case. You write in the manuscript that the hydrographs correspond to long term averages and do not represent the actual flow conditions during the periods of your sampling campaign. However, you do not pay attention to that basic fact when displaying the data: By plotting discharge and concentrations against the same time axis (Fig. 4) you give the impression that a flow rate value on day X is linked to the concentrations for the same day. However, this is not true. Therefore, this way of presenting and interpreting the data is not acceptable. Such figures would only be correct if you can provide the discharge data from the years of sampling. Should it not be possible to get access to this data, you have to adapt you data analysis accordingly. Because you neither have information about the actual flow for a given sampling date nor about the actual sequence of actual discharge from day to day you should not plot the data against the time axis. Instead you plot for example the concentrations against a selected quantile of flow rates for the corresponding Julian day. This would also be more to the point because you argue that there is a relationship between flow rate and DOC/CDOM concentrations irrespective of the Julian day.

**Response:** Thanks for your comments, I am really sorry for this misunderstanding which caused by my carelessness for the "note" in the caption for Figure 4 was not removed, thus the previous caption was not changed according to the updated flow data. In the previous version, the hydrograph is the average value, however, the in the current version, we tried the best and purchase the concurrent river flow data (we could provide these data in excel if necessary), so all the flow data are concurrent to the sampling year. I am really sorry for this misunderstanding, which is my fault not updating the caption in Figure 4 conveying the wrong information.

L.425-426, Fig. 3, Fig. 6: The data sets in the two figures seem not be fully consistent. When comparing for example Fig. 3d and 6d, there are 3 – 4 data points with DOC concentrations of 80 – 120 mg L−1 in Fig. 3d that are absent in Fig. 6d. How does it come? The same holds in the opposite direction with data of about 45 mg L−1 in Fig.

6c. What is the explanation?

**Response:** Thanks for your comments that really help to improve the manuscript. As you may know that the manuscript has revised at least two times, and some of the figures were updated, removed or added. The first version of the data processed by myself, and the figure 6 was provided in the last revised version, in which the data was processed by my students. The large data set were collected in different field campaigns, also some data were added in the revised manuscript, thus, inconsistency was caused due to our change of data processing person, and new data incorporated in the revised manuscript. We will further check the data set, and make sure all the data sets are consistent. Thanks again for pointing out the inconsistency, that really help for improving our manuscript, also we should bear in mind for being more careful during data processing and manuscript preparing.

L.451: I cannot see this low M values in Fig. 7B. Can you support your statement by a statistical metric?

**Responses:** the authors thank for the comments, we could provide the statistical metric in the revised manuscript.

L.462: Your selection of categories for M is rather arbitrary. Additionally, when looking at them in their entirety, it is obvious that there is a general pattern in that the slope decreases with increasing M (see figure in the attachment). Hence, the slope simultaneously depends on DOC and M. Because M is simply the ratio between aCDOM250 and aCDOM365, it follows that aCDOM275 is a function of DOC, aCDOM250, and aCDOM365. Instead of introducing first M and then classify M into categories, you better directly express aCDOM275 as a function of these three variables. This would make also any relationship that you find much easier to interpret.

**Response:** The authors really thank you for the thoughtful comments. Here, I might not make myself clear, we tried stepwise regression with CDOM absorption at 250 nm, 275nm, and 365 nm according to your kind suggestion, and found that there is no significant improvement for DOC estimate. It is two different things by incorporating M into regression model, and by grouping CDOM into different groups based on M value. In fact, if we try to incorporate aCDOM250 and aCDOM365 into the regression model, these two variables are just absorption intensity that won't help two much for the regression model. The essential thing here is to group CDOM of different waters into various group based on M values, thus each group roughly have similar absorption characteristics, which ultimately helps to improve the model accuracy. However, if incorporate M into regression model, which won't help for the accuracy.

L.489-491: This is confusing: In Fig. 8 you try to demonstrate that the aCDOM275 - DOC relationship depends on M, here you argue that one regression model is sufficient. Can you elaborate on this (apparent) contradiction?

**Response:** the authors thank you for the concern. As you might have noticed that these few high values of DOC and CDOM have leveraged the good relationship (Figure 9a), and remove these points will decrease the relationship between DOC and CDOM. Further, the DOC concentrations are still very high in Figure 9b, however the R-square value is only about 0.66. Thus, this model is roughly accurate for inland waters at national or sub-continental scale with large variation of DOC and CDOM. However, if accurate estimate of DOC through CDOM absorption needs to be achieved, then different types of waters should be classified, for instance based on M values which help to differentiate CDOM absorption efficiency. Further, the regression based on pooled data also give readers an approximate idea how the relationship between DOC and CDOM looks like with large data set covering different types of inland waters (river, freshwater, saline water, and urban water influenced by effluent and sewage discharge). If you suggest to remove this part, we would be happy to do so, thanks again for your consideration.

Minor aspects (style, wording etc.):

L.12: Has this algorithm been developed previously? Clarify.

**Response:** this algorithm was developed by Fichot and Benner in 2011, and it was clarified in the revised manuscript, thanks for the comments.

L.58: Replace acted by considered.

**Response:** the authors thank for the suggestion, we replaced ‘acted’ with ‘considered’.

L.60-61: Is this not trivial? What other sources exist?

**Response:** the authors thank for the comment, the sentence was rephrased. The sources are external, internal, and anthropogenic origin.

L.77: CDOM is not a single substance.

**Response:** the authors thank for the comment, we replaced ‘substance’ with ‘constituent’ in the revised manuscript.

L.110: What is the particular link between urban water sources and saline lakes?

**Response:** sorry for the ambiguous statement, there is no link between urban water sources and saline lakes, the authors rephrased this sentence in the revised manuscript.

L.168: Why don’t you provide this information for river samples?

**Response:** the authors thank for the concern, I might have clarified in the responses for the previous review and the resubmission for the current manuscript, we sampled quite a lot river sections, and some of these rivers or streams even don’t have name for it, particularly for these in Tibet Plateau, thus it is not practical for use to provide this information. We could provide these sampling station with a map if necessary.

L.219: I assume changed should be replaced by ranged.

**Response:** The authors really thank for the comment, your kind suggestion was incorporated in the revised manuscript.

L.258: Replace in by during the.

**Response:** your kind suggestion was incorporated in the revised manuscript, Thanks a lot for comment.

L.599–619: The references are not in the correct alphabetic order.

**Response:** The authors really thank for comment, the correct alphabetic order for the references were achieved in the revised manuscript.

L.643: The reference is not in the correct alphabetic order.

**Response:** The authors really thank for comment, the right order was corrected.

Fig. 1: Please explain what do you mean by Hydrological features.

**Response:** The authors thank for the concern, here the authors mainly talk about the lake morphologic characteristics. We could add note in the figure caption to explain what the hydrological features are in this context.

**Anonymous Referee #1**

This paper presents a series of regression equations between DOC concentrations and optical properties of the DOM across a range of water bodies in China. The authors have amassed an impressive data set, and applying this data set to questions of DOC biogeochemistry could make a useful contribution. Unfortunately the paper, as currently written, has some flaws that limit its value.

**Responses:** The authors thank for the positive comments on the impressive dataset, and also pointing out the flaws listed below, which we have addressed in detail after each comment or suggestion forwarded be the reviewer.

The paper focuses on two objectives stated in the Introduction, and a third objective that, for some reason, is presented in the Methods (lines 157-159). The objectives all are targeted at examining the relationship between DOC concentrations and optical properties, particularly absorbance at275nm or 440nm. The paper would be improved if it were structured around testable hypotheses, which I think the authors could do without too much additional work.

**Responses:** The authors really thank for the reviewer's instructive comments, we added testable hypotheses in the revised manuscript, and structured the layout of the manuscript according to the testable hypotheses. Thanks again for the valuable comments that really help for the improvement of the manuscript.

The primary means of data analysis is simple linear regression, and it appears that perhaps multiple linear regression was attempted (line 279-280). Surprisingly, no description of data analysis is provided in the paper (or the supplemental information). In fact, P values are not even provided for the regression analyses. Nor is there any indication of testing for normality or other assumptions for linear regression.

**Responses:** The authors thank for the comments. In the revised manuscript, descriptive statistical analysis were conducted for the data set, and assumptions for the linear regression were also tested for these regression analysis, in addition, P values for each regression model also were also provided in the revised manuscript.

Many of the graphs show that a single data point, or a couple data points, appears to be leveraging the relationship (e.g., Fig 3c, Fig 3e, Fig 3f, Fig 6d, Fig 6f, and others). In these cases, the validity of the regression equation is highly questionable.

**Responses:** The authors thank for the comments. We agree that a single data point or a couple data points might have improved the R-squares for these regression models, however, these data points are in situ measured values, and thus they reflect the natural situation. In the revised manuscript, we also did the regressions without these data points, and the results indicated that the R-squares did not affected much. We really appreciated your thoughtful comments. We could provide these regression metrics with and without these points in the revised manuscript.

In the case of Fig 8, it is not clear how the groupings were selected. The text mentions “trial and error” which suggests to be it was a very subjective process of selecting the M ranges for the groups.

**Responses:** The authors thank for the comments. In the current manuscript, the results presented in Figure 8 were derived based on trial and error testing of the regression modeling. The M value is used to classify CDOM into different groups, which might have similar CDOM absorption efficiency or absorption ability in each group, thus the CDOM absorption coefficient in each group should have similar relationship with DOC. However, how to determine the range for each group is still very subjective, we will further investigate and try to find a more reliable method for the grouping process. The testing results will be presented in the revised manuscript, thanks again for the comments.

I am a bit concerned about the holding time (up to 2 days) before filtration. Do the authors have any evidence that there was no degradation of DOC during the holding time? Some concern for chlorophyll-a. Also, it is questionable to collect and store DOC for optical analysis in HDPE bottles. Why was HDPE used instead of glass?

**Responses:** The authors thank for the very thoughtful comments. All the water samples ship back to laboratory and then stored in refrigerator at about 4℃ in the dark, thus the biodegradation should be very limited for DOC at low temperature. Similarly, the photo-degradation is also avoided since samples were kept in the dark. Some literatures also addressed this issue, and found that DOC is relatively stable, its change in two days at low temperature without photo-degradation should be neglectable. As for the HDPE sampling bottle, according to my knowledge, it is quite common to use HDPE bottles for field sampling to test water quality parameters, which has been previously cleaned by soaking in 0.5 mol $L^{-1}$HClfollowed by 0.1 mol $L^{-1}$NaOH for 24 h before heading to the field. According to Zhang et al. (2007), samples kept in two day before filtering would not cause obvious degradation for DOC concentration. Using glass bottle is not easy to ship back from field to laboratory during the bad road conditions, especially in Tibet or other remote areas where county roads are very common, which could cause severe damage of the glass bottles, thus HDPE bottles were used.

In the end, the authors state that SUVA is not an appropriate metric for the purposes of their study because its calculation includes DOC concentration. This left me wondering why it was included at all?

**Responses:** The authors thank you for the comments. Actually, we used both SUVA and M value (a250/a365) to characterize CDOM molecular weight qualitatively, and particularly SUVA is a very effective index for characterizing the molecular size of CDOM, thus we prefer the keep this part in the manuscript, but its linkage with CDOM grouping will be removed in the revised manuscript. Thanks again for your kind concern.

I think the Introduction could be shortened by as much as a third without any loss. Much of the introduction deals with remote sensing for DOC, but this paper does not address remote sensing directly; the background information on remote sensing could be greatly reduced within the Introduction and also the Discussion. I think developing some testable hypotheses and keeping the Introduction (and the whole paper) focused narrowly on those hypotheses would make for a shorter, and more readable, paper.

**Responses:** The authors really thank for the reviewer's very instructive comments. As you may see that there is another reviewer who also suggests to shorten this part, thus, the Introduction will be shortened in the revised manuscript.

I would strongly suggest separate Results and Discussion sections. As I read the paper it was not always clear when the authors were making statements based on their data, versus general statements from literature.

**Responses:** Again, the authors thank for the very thoughtful comments, and similar comment were also raised by the third reviewer (Professor P.K.Kowalczuk), we separate the Results and Discussion sections in the revised manuscript. We really appreciate this comments, which would definitely strengthen this manuscript.

Try to avoid vague statements such as "massive organic matter" (line 22) and "big variation" (line 230). The English in the paper is mostly correct, but it could certainly be improved if edited closely by a native English speaker.

**Responses:** The authors thank for the comments, your kind comments were adapted in the revised manuscript, further, and the authors have requested Professor Lin Li from IUPUI (Indiana University Purdue University, Indianapolis) edit the English in the revised manuscript.

**T. Kutser's comments**

Interactive comment on "A systematic examination of the relationships between CDOM and DOC in inland waters in China" by Kaishan Song et al.

T. Kutser tiit.kutser@sea.ee Received and published: 2 May 2017

Very impressive dataset and a very valuable research from remote sensing prospective. I definitely recommend to publish the paper after some minor modifications have been made.

The Authors mention in the text that using remote sensing for small ponds and lakes is problematic because of lack of appropriate remote sensing sensors. This may have been true some time ago (Palmer et al. 2015), but is not any more. Sentinel-2 imagery with 10 m spatial resolution is available globally. This kind of resolution is suitable for almost any pond, not speaking about lakes. Sentinel-2A data has been already used in mapping lake CDOM and DOC (Toming et al. 2016). Sentinel-2B was launched two months ago and is currently in testing phase. Meaning that in a few months 10 m spatial resolution imagery will be available with 5 days revisit time at the equator and about 2-3 day revisit time for most lakes in China. Besides that Landsat-8 imagery with 30 m spatial resolution is also available. There have been several papers recently showing the usefulness of Landsat-8 in mapping lake CDOM/DOC. Consequently, the image data is not a problem anymore. This strengthens the value of this research even more. I recommend to improve the remote sensing part of the manuscript showing that there is plenty of data available now free of charge with very high spatial and temporal resolution and your study will help to improve usefulness of this data at very local to global scales.

**Response:** the authors really thank Professor Kutser's valuable and very instructive comments. These valuable comments will be definitely helpful in revising the current manuscript, and the manuscript in preparation, which is mainly focused on establishing an algorithm with remotely sensed imagery data (e.g., Landsat OLI, Sentinel-2A, and Sentinel-3A/OLCI). For the current manuscript, the major objective is to examine the variation for the relationship between DOC and aCDOM($\lambda_i$), which has the potential to be applied for DOC estimate in inland waters. As stated in the introduction section of manuscript, the regression model slopes may vary significantly for different water types that ultimately affect DOC estimated results. Thus, we mainly focus on the relationship between DOC and CDOM absorptions for different types of waters. As you may see that the two other reviewers both suggested to remove the remote sensing part since no algorithm were established specifically for each types of waters being concerned in this study.

As aforementioned, your kind suggestions will definitely be incorporated in the manuscript in preparation, which is mainly focused on remote estimate of DOC concentration through the relationship between CDOM and DOC tracked in this study based on the optical classification of different types of waters. Thanks again for the very instructive comments.

SUVA is an important parameter used to describe carbon quality (e.g. in drinking water industry). Therefore, it is important to link remote sensing and SUVA more closely in the manuscript. Remote sensing of SUVA has been demonstrated at least in one recent paper cited several times by the Authors. I would recommend to add this reference in the 3.4 and strengthen the link between SUVA and remote sensing there.

**Response:** the authors really thank for the suggestions. Same like the responses to the exactly previous comments, the authors will retain the current manuscript major topic, and only focus on the relationship between DOC and CDOM, and the remote sensing part will be addressed in the manuscript in preparation. Thus, all you kind suggestions will be definitely incorporated in that manuscript, hope you could give more instructive comments on the ongoing one later on.

Is there any information available for seasonal variability? At least in boreal zone CDOM decreases from spring to summer and then starts to increase again (e.g. Kutser 2012), but how about the CDOM-DOC or DOC-SUVA relationships? This would be a very interesting piece of information.

**Response:** thanks for the valuable comments, certainly, the attempts to examine the temporal variability between DOC and CDOM would be very interesting piece of information, however, there only one visit for most of the waters being sampled. But, we have water samples collected in three river sections in weekly or bi-weekly time steps, which indicated that CDOM-DOC relationship (see Figure 5) may change with different rivers. The head water section shows higher regression slope, while river with certain amount of anthropogenic pollution will result in decreased regression slope value (Figure 5c, sample were collected in the Songhua River, which was polluted by sewage waters and other anthropogenic sources).

In general the paper is written well. There are some minor errors in names (e.g. must be Gulf of Finland not Finish Gulf in row 119) and some sentences can be modified, but the text is easily readable.

**Response:** the authors really thank for the valuable comments, these minor errors and some of the problematic sentences were corrected or rephrased in the revised manuscript, thanks again for the positive comments.

**Responses to PK Kowalczuk's comments:**

Dear Dr Stamm,

After reading the manuscript by Song et al., submitted to Hydrology and Earth System Science and coded hess-2017-179, I think that this study should be consider for publication in this journal after major revision.

General opinion

This study presented results of extensive field studies on relationships between absorption of Chromophoric Dissolved Organic Matter and Dissolved Organic carbon in different water bodies conducted in continental China in different climatic zones. Authors found overall very good correlation between DOC and CDOM absorption coefficient at selected wavelengths, 275 and 400 nm. They have showed that both values of the slope coefficient of the linear regression between considered variables and values of determination coefficient varied considerably between studied water bodies. Author have also proposed a solution to minimize those variations by groping data according to spectral index M, which gave quite uniformed results in respect of the calculated $R^2$, but still there was a significant variability of in regression slope coefficient values. This study proved that application of simple optical measurements could be applied in accurate and reliable estimation of DOC content in fresh water bodies in continental China.

My overall good opinion on this manuscript is somehow hampered by two major flaws: the introduction is overlong with many repetitions especially in regarding remote sensing applications, and Author have written their results together with discussion and it is very difficult for reader to judge when Author presents their own results and when they discuss with published results.

I strongly recommend to reduce introduction to maximum 3-4 pages from current 5, reduce the implications to remote sensing in Introduction. This is particularly redundant because Author have not presented a link between their regression analysis and remote sensing reflectance – the geophysical variable that is physically measured by radiometers placed on spaceborne or airborne platforms. I also strongly recommend that Author shall present their own results and later give their interpretation in Discussion.

**Responses:** The authors thank for the positive comments on the overall quality of the manuscript, particularly for the data set. Also, the authors thank for Professor Kowalczuk pointing out the two major flaws, which we have addressed in the revised manuscript by shortening or removing some unnecessary parts relevant to remote sensing application in the Introduction section; further, we will separate Results section with Discussion section in the revised manuscript.

Detailed comments.

Abstract

Page 1 Lines 12 – 13

“An algorithm has been developed to retrieve DOC via CDOM absorption (aCDOM) at 275 and 295 nm for coastal waters, but it is still unclear for the relationship between DOC and aCDOM in other types of waters.”

This sentence has no support in presented results. Authors have derived regression relationship between aCDOM(275) and aCDOM(440) but did proposed any remote sensing algorithms in the way it usually developed by the ocean color remote sensing/ocean optics community. Consider to remove this sentence. Abstract shall described your own findings - and shall not contain discussion. When you mention spectral values of aCDOM(ïA¸ˇn) – use the symbol l in parenthesis and then indicate specific wavelengths.

**Responses:** The authors thank for the instructive and specific comments, we removed this sentence in the revised manuscript. The very instructive comment for presentation of aCDOM by including specific wavelengths was incorporated throughout the manuscript during the revision.

Page 2 Lines 28 – 30

Our results indicated the relationships between CDOM and DOC are variable for different inland waters, and therefore remote sensing models for DOC estimation through linking with CDOM absorption need to be tailored according to water types.

This sentence is not precise. Author developed empirical relationships between DOC and aCDOM(ïA¸ˇn) but not proposed any remote sensing algorithm. Algorithm need to be developed for different water types and later tested and validated and finally optimized. Please rewrite this sentence. It would be OK in discussion as it points the future direction of your work. Abstract shall briefly and comprehensively present your results.

**Responses:** The authors thank for the thoughtful comments, we rewrote this sentence in the revised manuscript to avoid misunderstanding with remote sensing of DOC through the linkage with CDOM, we will try the best to achieve a concise and comprehensive abstract in the revised manuscript.

Introduction

Please reduce length of introduction significantly. Please try to use separate paragraphs to present current knowledge of CDOM biogeochemistry, optics and remote sensing applications to study part of the Earth carbon pool. Just one paragraph thread is sufficient. Avoid later repetitions.

**Responses:** The authors thank for the comments, the Introduction section was separated into current knowledge of CDOM biogeochemistry, optics and remote sensing applications. Thanks again for the suggestions that really make the Introduction presented more logically.

Page 4 Lines 77 – 95

There are a lot overstatements or incorrect sentences in this paragraphs – examples below.

“CDOM is a major light-absorbing substance, which is responsible for much of the color in waters (Reche et al., 1999). “

First of all CDOM is not a substance – it is a heterogeneous mixture of water soluble organic compounds. CDOM have specific optical properties, it absorbs light in UV and visible spectral range and those optical properties change spectral properties and light intensity in water column. From physical point the water color, that can be sensed by human eye (or radiometer) is a ratio between scattering coefficient and sum absorption and scattering coefficients. As CDOM absorption contributes strongly to total absorption coefficient and thus changes the b(ïA˛ˇn)/(a(ïA˛ˇn)+b(ïA˛ˇn)) ratio, the visual effect of CDOM presence in water is change of color to yellowish (or brownish when CDOM concentration is high). That is why first definition of CDOM was “yellow substance”.

**Responses:** The authors thank for the very detailed comments, which really help for clarifying the role that CDOM plays in water color remote sensing, or the water leaving radiance by optically active constituents. Your kind suggestions were absorbed and incorporated in the revised manuscript, and some of the inappropriate statements were rephrased.

Page 5 Lines 78 – 80

“The chemical structure and origin of CDOM can be characterized by its absorption coefficients (aCDOM(λ)) and spectral slopes (De Haan and De Boer, 1987; Helms et al., 2008).”

CDOM absorption coefficient aCDOM(ïA˛ˇn) cannot characterized CDOM chemical structure – first CDOM is a mixture of countless compounds, second CDOM absorption spectrum is featureless and monotonic and does not contain any spectral peaks that could be associated with specific compounds. Spectral slope of CDOM absorption spectrum is only an approximate proxy of the relative contribution of fulvic acids and humic acids in this mixture, see Carder et al 1999 for details. There many physical and microbial process influencing effective values of the spectral slope coefficient, so

Author shall be cautious using such a definitive statements. All spectral indices cited in following sentences, like SUVA(254), SR etc shall be cited correctly as defined by their Author. Those spectral indices are only optical proxies correlated with sum physical (SR – molecular weight) or chemical (SUVA(254) – relative aromaticity) characteristics of CDOM.

**Responses:** The authors really thank for the reviewer's very instructive comments. These helpful suggestions or comments were adopted in the revised manuscript.

Page 5 Lines 83 – 85

"...while the ratio of CDOM absorption at 250 to 365 nm (aCDOM(250/365), herein, M values) ..."

This ratio shall be defined as aCDOM(250)/aCDOM(365)-not aCDOM(250/365)–this a formal error – please correct throughout the whole manuscript text.

**Responses:** The authors thank for the instructive comments. The authors replaced "aCDOM(250/365)" with "aCDOM(250)/aCDOM(365)" throughout the revised manuscript.

"...to track the changes in DOM molecule weight (De Haan and De Boer, 1987; Zhang et al., 2010) and absorption intensity (Song et al., 2013)."

The ratio of two absorption coefficient at two different wavelengths tell nothing about intensity of the absorption process-it only give a relative information who much absorption is stronger(weaker) at one wavelengths relative to other wavelength. Magnitude of ratio by spectral values of absorption coefficients could be an effect of some reasons – according to De Haan and De Boer, 1987 – change in molecular weight). Please cite literature correctly.

**Responses:** The authors really thank for the reviewer's very instructive comments. The right citations were provide in the revised manuscript.

Page 5 Lines 91 – 93 “It should be noted that aCDOM(440) is usually used by remote sensing community due to this wavelength is less affected by phytoplankton (Lee et al., 2002).”

This sentence is a complete nonsense. The principle and highest phytoplankton pigments absorption is located at 443 nm. Therefore the effect of phytoplankton absorption on total absorption is highest here. The CDOM absorption in visible range have overlapps with phytoplankton pigments absorption at 443, and this effect was introducing errors in ocean color remote sensing algorithms for retrieval of chlorophyll a concentration. In most cases chlorophyll a was overestimated by those algorithms that were not taking into account CDOM absorption at 443 nm. That was a reason for reporting aCDOM(443) in literature, and inclusion of this parameter particularly in semi0anlytical remote sensing algorithms.

**Responses:** This comments is very instructive, that really help me understand the underlying reason why aCDOM(443) was reported in remote sensing community. Thanks again for the reviewer’s valuable comments.

Page 6 Lines 102 – 104

“With compositional change, the absorption feature of CDOM and its relation to DOC varies correspondingly, but the relationship between CDOM and DOC is far from solved (Gonnelli et al., 2013).”

CDOM is a complex mixture of heterogeneous organic compounds, each having individual optical properties. Therefore, the estimation of the universal bulk carbon-specific CDOM absorption coefficient, aâA¸˝OCDOM(λ), defined as the ratio aCDOM(λ)/DOC, seems almost unfeasible (Woz´niakandDera,2007). Therefore value of aâA¸˝OCDOM(λ) may change an order of magnitude in short spatial scale (e.g. Del Vecchio and Blough, 2004; Kowalczuk et al., 2010, Mar Chem 118, 22-36).

**Responses:** The authors really thank for the instructive comments, which has been incorporated in the revised manuscript, and these references recommended by the reviewer were also adopted during the manuscript revision.

Please consider to rewrite a whole paragraph between lines 77 – 105

**Responses:** Again, the authors thank for the comment, and the whole paragraph was rewritten in the revised manuscript, and all the reviewer's comments for the whole paragraph listed above were also incorporated during rewriting of this part.

Page 6 Line 119

"... for example the Finish Gulf (Kowalczuk et al., 2006) ..."

Wrong citation. Paper by Kowalczuk et al., (2006) said nothing about relationship between aCDOM(350) and DOC. This relationship has been presented for Baltic Sea surface waters (not Gulf of Finland) in paper by Kowalczuk et al., (2010) (Oceanologia, 52(3), 431-471). Remove citation to Kowalczuk et al., 2006.

**Responses:** The authors thank for the very specific comment, the right study site and right reference literature were incorporated in the revised manuscript.

Page 7 Lines 131 – 134

" According to Fig.1, the proposed hypothesis suggests that the main source of ...."

Repetition. Please try to keep different thread together, do not repeat things that you have said before.

**Responses:** The authors thank for the valuable comments, these repetitions were avoided in the revised manuscript.

Materials and Methods

Page 9 Line 178

" ... converted to in situ salinity units (PSU) in the laboratory. "

The salinity in practical salinity scale has no units – it's a ratio of water electrical conductivity measured at given temperature and pressure to ratio of electrical conductivity of artificial sea water measure at standard temperature and pressure. This phrase shall be written as follow:

... converted to in situ salinity, expressed in practical salinity scale (PSU), in the laboratory.

**Responses:** The authors really appreciated the valuable suggestion, which has been adopted in the revised manuscript.

Page 9 Line 190

“ Chlorophyll-a (Chl-a) was extracted and concentration was measured using a Shimadzu UV-2050PC spectrophotometer (Song et al., 2013).”

Detailed method of spectroscopic measurements of chlorophyll a concentration shall be given, or at least a proper reference to equation that converts measure absorbance of pigments extract to chlorophyll a concentration shall be cited. Song et al., are not authors of this method, it has been proposed first by Strickland and Parsons, 1972.

**Responses:** The authors thank for the instructive comments, and the proper citation was added in the revised manuscript. Strickland JDH, Parsons TR (1972) A practical handbook of seawater analysis. Fisheries Board of Canada. Ottawa.

Results and discussion

The whole section shall be rewritten to two sections: Results - where Authors presents their own results, and Discussion – where Authors give interpretation of their results.

**Responses:** The authors for the instructive comments, as aforementioned, this section was divided into Results and Discussion sections in the revised manuscript.

Page 11 Line 219

Chl-a concentrations (46.44±59.71 μg/L) changed from 0.28 to 521.12μg/L, with the mean of 46.44 μg/L.

Redundancy – you give the same value of averaged chlorophyll a concentration twice in the same sentence. Correct.

**Responses:** The authors for the instructive comments, the redundancy was avoided in the revised manuscript by deleting "with the mean of 46.44 μg/L".

Page 14 Lines 285 – 287

Phytoplankton degradation may contribute relative large portion of CDOM and DOC in these water bodies (Zhang et al., 2010), due to the lower molecular weight, its absorption is different from that derived from terrestrial systems (Helms et al., 2008).

Wrong citation again. Helms et al., 2008 neither worked in fresh water bodies nor studied phytoplankton degradation products. They have focused on photobleaching effect on spectral slope and have established a spectral slope ratio as proxy for molecular weight. I do not see any information on spectral slope ratio in this paper – so why do you discuss with Helms et al., 2008. This paper does not present any CDOM absorption spectral slope data at all.

The same wrong citation to Helms et al., (2008) repeated on the same page at line 291.

**Responses:** The authors thank for the comments. There might a misunderstanding for the reference, here the authors try to say that phytoplankton degradation may change the spectral slope due the change of molecular weight for some components of the mixture compounds. The wrong citation was removed, and the proper ones were added in the revised manuscript.

Page 14 – 15, Lines 297 - 300

"As suggested by Brezonik et al. (2015) and Cardille et al. (2013), CDOM in the eutrophic waters or those with very short resident time may show seasonal variation due to algal bloom or hydrological variability, while CDOM in some oligotrhopic lakes or those with long resident time may show an opposite pattern."

This is a part of discussion, but I do not know which part of results is discussed here. Authors did not spent a lot of time on trophic status of studied lakes. The chlorophyll a is mentioned only in one sentence at the beginning of Results section.

**Responses:** The authors really appreciated this comments. This sentence was removed since it did not have a strong link with the current study, and we did not pay much attention to the impact of eutrophication on CDOM absorption characteristics.

Page 15 Line 318

" ... were found and less colored portion of DOC was presented in waters in semi-arid to arid regions ... "

I did not found any data on aCDOM(ïA˛ˇn)/DOC relationship in this paper, neither in the text, tables nor figures. What Authors refer to?

**Responses:** The authors thank for this comments, and sorry for the misleading. In the first submitted version, the relationship between DOC and CDOM were analyzed based on the SUVA254 classification, which has connection with aCDOM(ïA˛ˇn)/DOC relationship, this part was not full removed from the previous version, that caused the misunderstanding. We remove this sentence in the revised manuscript, thanks again for the valuable comments.

Page 16 Line 339

" ... which is consistent with the findings from Helm et al. (2008) ..."

Wrong citation again. There is no single line in paper by Helms et al., (2008) on DOC vs. aCDOM(l) relationship.

**Response:** The authors thank for the comment, there might a misunderstanding for the expression. Here the author did not state the relationship between DOC and CDOM, rather, we tried to say that CDOM in head waters tend to have high molecular weights, thus lower spectral slope values, which has nothing to do with the relationship between CDOM-DOC. To avoid misunderstanding, we rephrased this sentence in the revised manuscript.

Page 19 Line 397

" ... ice and snow cover shielded out most of the solar radiation that might cause a series of biochemical process for CDOM contained in water ..."

What specific processes Authors refer to? Citation need to support this statements, otherwise I suggest to delete it.

**Response:** Thanks for the comment, this sentence was deleted in the revised manuscript.

Page 20 Line 428

"This has important implication for remote sensing of DOC through the CDOM absorption as a bridge (Zhu et al., 2014; Kuster et al., 2015; Brezonik et al., 2015)."

What kind of bridge CDOM absorption is ?

**Response:** Thanks for the comment, we rephrased this sentence in the revised manuscript to make it clear. Here, the authors try to say that CDOM is a optically active constituent that can be remotely sensed, but not DOC. Remote sensing of DOC is based on the relationship between DOC-CDOM, thus CDOM absorption is a bridge for DOC estimate through remotely sensed data.

Page 23 Line 491

"Most of the paired data sitting close to the regression line except some scattered ones."

Very bizarre sentence that contains no useful information. Delete it.

**Response:** Thanks for the comment, this sentence was deleted in the revised manuscript.

Conclusion

Delete first two sentences that refer to remote sensing. This paper is about DOC vs.

aCDOM(ïA¸ˇn) relationships in different water bodies not about remote sensing algorithms.

**Response:** The authors really thank for the very valuable comments, the first two sentences were removed as suggested.

Page 24 Lines 514 – 516

The slope values of saline lakes and urban waters were close to unity, slope values of river water were highest (∼ 3.1), and slope values of other water types were in between. Repetition of results – consider to delete.

**Response:** The authors really thank for the very valuable comments, these repetitive statements were removed in the revised manuscript.

Acknowledgements “Last but not the least, the authors 534 would like to thank the editor and two anonymous referees .....” Has this manuscript been submitted to other journal and reviewed before current review?

**Response:** thanks for the comment, yes, this manuscript was submitted to HESS in 2016, and the handling editor (Professor Stamm) suggested to resubmit to HESS, thus the previous acknowledgements were kept.

Figure 3 and 5, 8, 9

Y axis legend on figure 3, 5, 8, 9

Is: aCDOM275 (m-1), should be aCDOM(275) [m-1] – please correct accordingly in all specified figures.

**Response:** The authors really thank for the very valuable comments, Figure 3, 5, 8, and 9 were reproduced with the suggested labels.

Figure 4

Add information to legend – what CDOM absorption coefficient, aCDOM(ïA˛ˇn) is presented on 3 panel of Figure 4.

**Response:** The authors really thank for the very helpful comments, CDOM absorption coefficient wavelength of three panels in Figure 4 were added in the revised manuscript.

Figure 6

The same remark as for figures 3, 5, 8, 9 – correct Y axis legend to aCDOM(440) [m-1] Figure 6.

**Response:** The authors really thank for the very valuable comments, the Y axis legend for Figure 6 was corrected in the revised manuscript.

Figure 7 legend the ratio shall be defined as aCDOM(250)/aCDOM(365) - not aCDOM(250/365). Panel a Y axis SUVA(254) dimension is [m2 g-1].

**Response:** The authors really thank for the very valuable comments, all your kind suggestions were incorporated in the revised manuscript.

Figure 9

Scales on panel c graph shall be expressed in decimal logarithms log-log. The regression shall be fitted to power function–so it will be linear in log-log scale. See examples in paper by Kowalczuk et al., (2010) (Oceanologia, 52(3), 431-471).

**Response:** Thanks for the valuable comments, panel c of figure 9 was reproduced as suggested.

Table 2

Add units to DOC and aCDOM(440) as in Table 1.

**Response:** Thanks for the suggestion, units for DOC and aCDOM(440) were added in Table 2.