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Advances in Space Research 53 (2014) 1081–1091

ADVANCES IN SPACE RESEARCH (a COSPAR publication)

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Response of dissolved oxygen and related marine ecological parameters to a tropical cyclone in the South China Sea

Jingrou Lin [a,b,c], Danling Tang [a,b,*], Werner Alpers [d], Sufen Wang [a]

[a] Research Center for Remote Sensing of Marine Ecology and Environment (RSMEE), State Key Laboratory of Tropical Oceanography, South China Sea Institute of Oceanology, Chinese Academy of Sciences, 164 West Xingang Road, Guangzhou 510301, PR China

[b] Graduate University of Chinese Academy of Sciences, 19A Yuquan Road, Beijing 100049, PR China

[c] South China Sea Marine Engineering and Environment Institute of State Oceanic Administration, Guangzhou 510300, PR China

[d] Center for Marine and Atmospheric Sciences, Institute of Oceanography, University of Hamburg, Bundesstr. 53, D-20146 Hamburg, Germany

Received 5 April 2013; received in revised form 29 December 2013; accepted 7 January 2014
Available online 13 January 2014

Abstract

It is well known that tropical cyclones can cause upwelling, decrease of sea surface temperature, increase of chlorophyll-a (Chl-a) concentration and enhancement of primary production. But little is known about the response of dissolved oxygen (DO) concentration to a typhoon in the open ocean. This paper investigates the impact of a typhoon on DO concentration and related ecological parameters using in situ and remote sensing data. The in situ data were collected 1 week after the passage of the super-typhoon Nanmadol in the northern South China Sea in 2011. An increase in DO concentration, accompanied by a decrease in water temperature and an increase in salinity and Chl-a concentration, was measured at sampling stations close to the typhoon track. At these stations, maximum DO concentration was found at a depth of around 5 m and maximum Chl-a concentration at depths between 50 and 75 m. The layer of high DO concentration extends from the surface to a depth of 35 m and the concentrations stay almost constant down to this depth. Due to the passage of the typhoon, also a large sea level anomaly (21.6 cm) and a high value of Ekman pumping velocity (4.0×10^{-4} m s^{-1}) are observed, indicating upwelling phenomenon. At the same time, also intrusion of Kuroshio waters in the form of a loop current into the South China Sea (SCS) was observed. We attribute the increase of DO concentration after the passage of the typhoon to three effects: (1) entrainment of oxygen from the air into the upper water layer and strong vertical mixing of the water body due to the typhoon winds, (2) upwelling of cold nutrient-rich water which stimulates photosynthesis of phytoplankton and thus the generation of oxygen, which also increases the DO concentration due to cold water since the solubility of oxygen increase with decreasing water temperature, and, possibly, (3) transport of DO enriched waters from the Western Pacific to the SCS via the intrusion of Kuroshio waters.

Keywords: Dissolved oxygen; Tropical cyclone; South China Sea; Upwelling; Remote sensing; Kuroshio

1. Introduction

Tropical cyclones, typhoons or hurricanes are strong wind events in the weather system, which influence the upper ocean dynamics and the ecosystem, in particular upwelling, water temperature, salinity, chlorophyll-a (Chl-a) concentration, primary production (Price, 1981; Price et al., 1994; Liu et al., 2002; Xu et al., 2005; Chang et al., 2006; Shi and Wang, 2007; Chen et al., 2009; Siswanto et al., 2008, 2009; Smitha et al., 2006; Yang and Tang, 2010; Hung et al., 2010; Hung and Gong, 2011; Chung et al., 2011) and fish abounce (Yu et al., 2013). Typhoons can induce upwelling and thus transport nutrient-rich water to near-surface water levels (Zheng and Tang, 2007; Chen et al., 2007; Chang et al., 2008; Siswanto

* Corresponding author at: Research Center for Remote Sensing of Marine Ecology and Environment (RSMEE), State Key Laboratory of Tropical Oceanography, South China Sea Institute of Oceanology, Chinese Academy of Sciences, 164 West Xingang Road, Guangzhou 510301, PR China. Tel.: +86 13924282728.

E-mail address: lingzistdl@126.com (D. Tang).

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http://dx.doi.org/10.1016/j.asr.2014.01.005

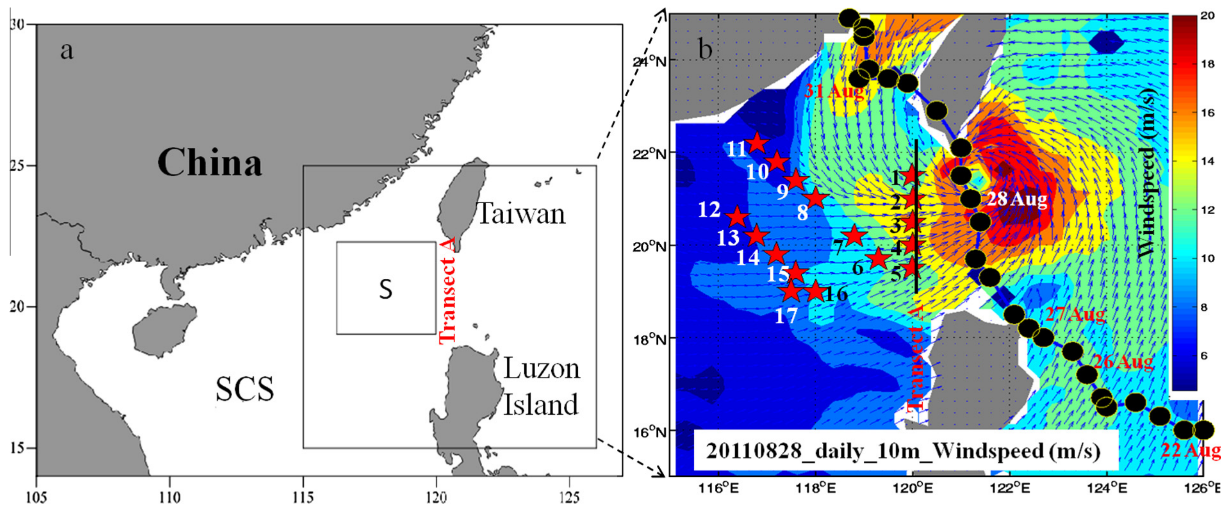

Fig. 1. (a) Location of the study area (box S). (b) Track of the super-typhoon Nanmadol between 22 and 30 August 2011, location of the 17 sampling stations in the study area during the 2011 cruise, and the near-surface wind field retrieved from ASCAT data acquired on 28 August. The Stations 1–5 are aligned along the transect A (marked by a black line).

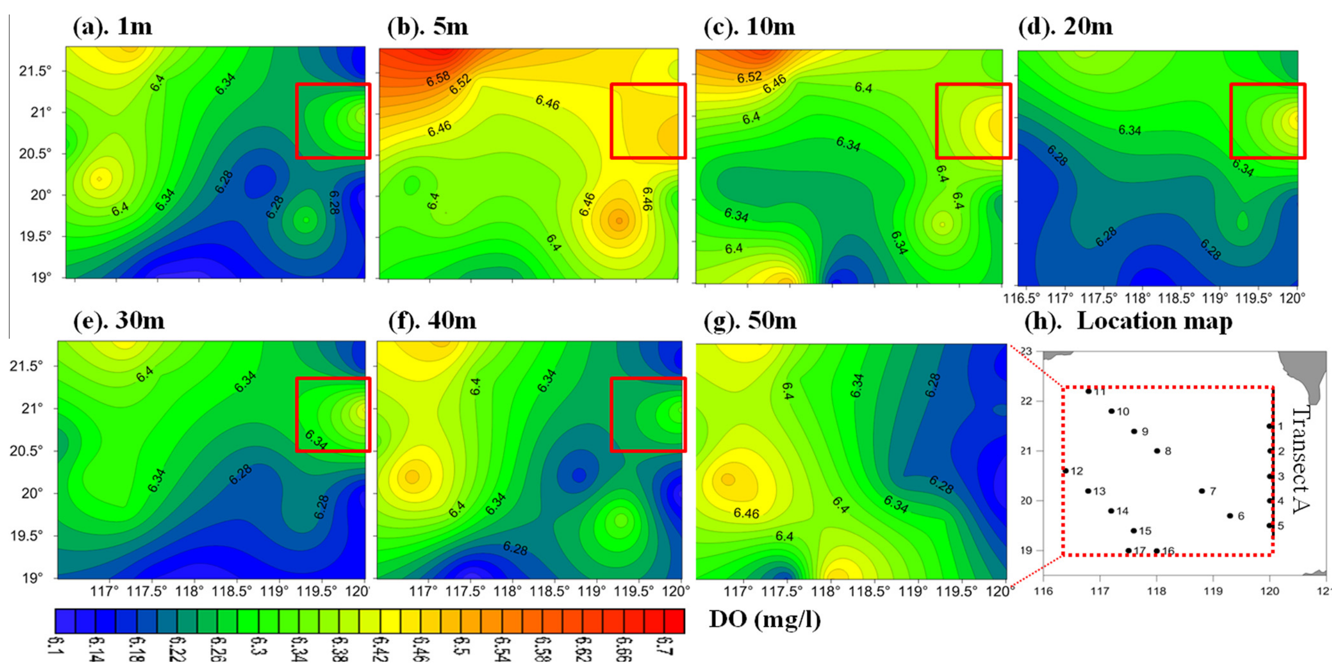

Fig. 2. Horizontal distribution of DO concentration (in mg l^{-1}) at different depths at 19–22°N, 116–120°E (a–g). Location map (h).

et al., 2008; Su and Pohlmann, 2009; Pun et al., 2011). Furthermore, they cause strong vertical mixing of the upper water layers above the thermocline (Dickey et al., 1998; Jacob et al., 2000; Lin et al., 2003a,b; Lin, 2012; Shang et al., 2008). Previous studies mainly have focused on the effect of typhoons on phytoplankton bloom (i.e., strong increase of Chl-a concentration), increase in primary productivity, and decrease in water temperature (Cione and Uhlhorn, 2003; Smitha et al., 2006; Chen et al., 2007; Zhao et al., 2009; Sanford et al., 2011). But we know of no paper dealing with the response of dissolved oxygen (DO) concentration to typhoons in the open ocean.

DO in sea water is critical to marine life and primary productivity. It is mainly influenced by composition and decomposition of organic matter, by dynamic processes in sea water, and by air–sea interactions (Han, 1995). The depth of maximum DO concentration is usually lies above the depth of maximum Chl-a concentration (Lin et al., 2001, 2003a,b). Furthermore, there is an inverse relationship between DO concentration and water temperature (Long et al., 2006; Ning et al., 2009).

There exist several papers dealing with the response of DO concentration to hurricanes or typhoons in estuaries. In estuaries, DO concentration can decrease in a short time