Demonstration of a new indicator for studying upwelling in the northern South China Sea*

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Abstract

In order to demonstrate that silicate (SiO_3-Si) can be used as an indicator to study upwelling in the northern South China Sea, hierarchical cluster analysis (CA) and principle component analysis (PCA) were applied to analyse the metrics of the data consisting of 14 physical-chemical-biological parameters at 32 stations. CA categorized the 32 stations into two groups (low and high nutrient groups). PCA was applied to identify five Principal Components (PCs) explaining 78.65% of the total variance of the original data. PCA found important factors that can describe nutrient sources in estuarine, upwelling, and non-upwelling areas. PC4, representing the upwelling source, is strongly correlated to SiO_3-Si. The spatial distribution of silicate from the surface to 200 m depth clearly showed the upwelling regions, which is also supported by satellite observations of sea surface temperature.

1. Introduction

Coastal upwelling is an important marine process that has been studied worldwide because of its significant impacts on biogeochemical cycles, primary productivity and fisheries (Prego et al. 2007, Woodson et al. 2007). The process can re-fertilize the surface water with high levels of nutrient by uplifting nutrient-rich subsurface water and thus increase the growth of marine phytoplankton in the surface layer (Shen & Shi 2006, Prego et al. 2007). There are several famous coastal upwelling systems in the world: the Benguela Current (Monteiro & Largier 1999), the California Current (di Lorenzo 2003), the Peru-Chile Current (Nixon & Thomas 2001, Mohtadi et al. 2005) and the Canary Current (Pelegrí et al. 2005). These upwelling systems are produced by the interaction between favourable winds and the topography (Woodson et al. 2007), often involving offshore Ekman transport or surface currents.

The upwelling systems in the northern part of the South China Sea (SCS) are still not well understood by marine scientists because of the influence of the Kuroshio Current (KC) passing through the Luzon Strait in the deeper layer (Su & Wang 1990, Hu & Liu 1992, Huang et al. 1992, Chen & Huang 1996), the complex topography (Morton & Blackmore 2000) and the dynamic climatology. There are four coastal upwelling regions in the northern part of the SCS: the east of Guangdong Province and Hainan Province (Han 1998, Wang et al. 2006, 2008, 2011), the Taiwan Shoals (TSLS) located southwest of Taiwan (Wu & Li 2003), and the perennial cold cyclonic eddy (Wu 1991, Huang et al. 1992; Soong et al. 1995, Liao et al. 2006) to the south-west of the Dongsha Islands (PIS).