Suspended Sediment and Light Attenuation Characteristics in Singapore Waters

MSc. Thesis
7 November 2012
Toh Han Loong
Abstract

Light is attenuated by materials present in the water column by scattering and absorption. The knowledge of light attenuation and its contributing factors influencing visibility/turbidity is unknown in Singapore waters. This MSc thesis consists of field measurement, laboratory experiment and numerical modelling in 2 parts; the first is the parameterisation of light attenuation coefficient while the second is the numerical modelling of underwater light field and visibility. The objectives of this thesis are; a) to determine the dynamics of optical properties in Singapore waters, b) to investigate factors contributing to light attenuation in Singapore waters and c) to model underwater light field and visibility using Hydrolight and Delft3D WAQ. This first component addresses the dynamics of light attenuation (in relation to tides), the spectral nature of the underwater light field and the effects of particle size distribution (PSD) to light scattering. During spring tide, the optical properties vary 10 – 40 % from low to high tide while the variation during neap tide is negligible. Higher TSS during low tide is advection dominated while lower TSS during high tide is suspension dominated. Optical properties during high tide are suspension dominated and advection dominated during low tide. Relative contributions of CDOM, chlorophyll and sediment to light attenuation coefficient $K_d$ were found to be 1.4 – 6.5 % (average of 3.3 %), 1.3 – 62 % (average of 24 %) and 31.3 – 95.2 % (average of 70 %) respectively. The second component investigates underwater light field and visibility using numerical modelling. Underwater light field shows that light attenuation depend mostly on the vertical variation of optically significant constituents and only weakly dependent on light structure, cloud cover and fluorescence. The modelled $K_d$ from Hydrolight ranges from 1.2 to 2.3 m$^{-1}$ with lower range of $K_d$ in chlorophyll dominated waters while the empirical estimations underestimate $K_d$ (PAR) compared to the modelled $K_d$ from Hydrolight. The modelled Secchi depth, $S_d$ ranges from 0.6 – 1.4m corresponding to euphotic depth $z_{eu}$ of 2.0 – 3.8 m with deeper $z_{eu}$ for chlorophyll dominated waters. The visibility throughout the model domain is generally lowest during NE followed by SW monsoon and IM period with evidence of spatial homogeneity for all monsoons. The visibility model reproduces the recorded $S_d$ reasonably well except for Johor Strait and sheltered areas in WCP. The $K_d$ variation coincides with SSC variation with no phase difference; the visibility is lowest during spring low tide and highest during neap high tide. Convective interaction between the diurnal and semidiurnal components is important in offshore locations while the non-linear flux term contributes in the shallow water of Johor estuary. The residual turbidity in Singapore waters is due to tides (semi diurnal and diurnal spring neap interactions) and non-tides (monsoonal effect) in approximately equal magnitude during monsoons. The results from this thesis are applicable in coastal engineering, ecological and remote sensing applications.