ANALYZING THE SPATIAL AND TEMPORAL VARIABILITY OF WATER TURBIDITY IN THE COASTAL AREAS OF THE UAE USING MODIS SATELLITE DATA

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Abstract

The Arabian Gulf is known to have very high turbidity compared to other water bodies. This high turbidity is mainly due to the settling of airborne dust carried out from the surrounding desert areas. Other local activities such as land reclamation and desalination plant discharges have also increased the water turbidity in the near-coastal areas. Turbid water could become warmer when the suspended particles absorb the heat coming from the sunlight which leads to reduction in the oxygen levels in the water which could harm the aquatic ecosystem. In addition, high turbidity affects the photosynthetic process of the plants and algae because the presence of suspended particles increases the light scattering which may lead to a decrease in the oxygen concentration in the water. Sediment deposition may also accelerate the filling of shallow areas.

The objective of this project is to develop satellite-based tool to produce daily assessment of water turbidity in UAE coastal areas. Ten years of daily satellite data acquired by the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments have been collected for this project. Two MODIS sensors are presently orbiting the earth onboard of the NASA Terra and Aqua satellites (morning pass and afternoon pass) providing twice daily coverage of the UAE coastal areas at medium spatial resolution ranging from 250-m to 1000-m.

Keywords: UAE, Turbidity, MODIS, The diffuse attenuation coefficient at 490nm.

1 INTRODUCTION

Various satellite instruments can be used to estimate water turbidity after proper calibration and algorithms implementation. One of these instruments, the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments on board of NASA Terra and Aqua satellites (morning pass and afternoon pass) provide daily global coverage at medium spatial resolution (250-m to 1000-m), and thus can serve as excellent candidates to map coastal water turbidity on daily basis (providing cloud free and clear sky conditions). For small-scale regions that require higher spatial resolutions, Landsat ETM+ data at 30-m resolution can be also used to retrieve water turbidity. The scope of this work is focused on adapting, calibrating and validating existing satellite-based tools to map water turbidity along the Abu

Dhabi coastline (Fig. 1). MODIS is by far the most used sensor by the ocean color community in the last 10 years. Both MODIS sensors (Aqua and Terra) have the most optimal spatial and temporal resolutions (twice-daily coverage at 250-m to 1-km resolution). Water quality in many coastal regions is very dynamic experiencing fast changes (day to week) in response to wind, tidal movements, runoff (if any), reclamation activities and dust deposition. Less-frequent measurements may potentially induce temporal aliasing in statistics. This, however, depends on how fast the study region changes. With no information on the temporal dynamic of turbidity in Abu Dhabi coastline, it is safer to choose a high-frequency instrument such as MODIS, at the compromise of lower spatial resolution.

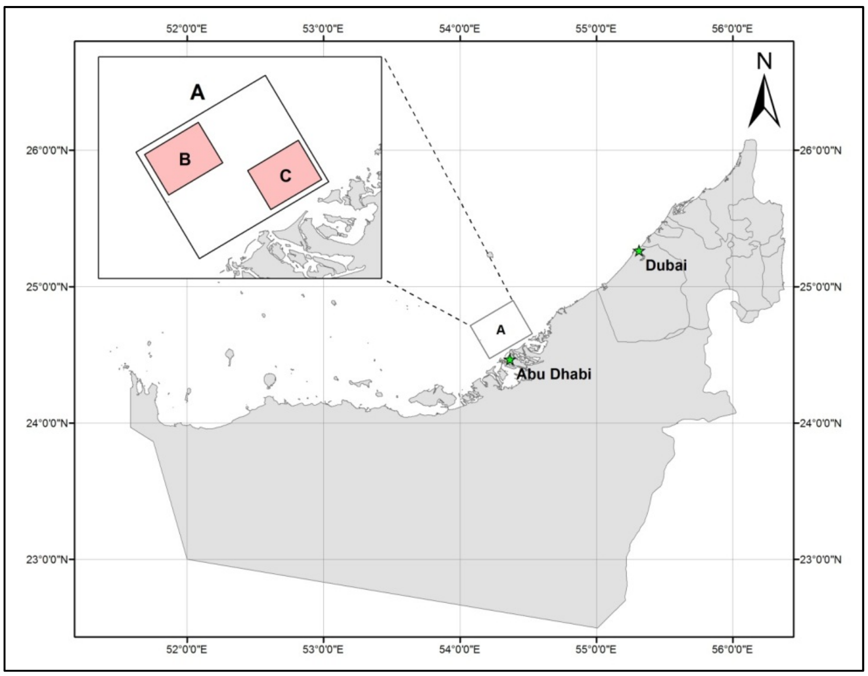

Fig. 1. Study area (A) the actual study area 30x30 km^2 ;(B) and (C) the subareas 12 x 12 km^2 within the actual study area.

The Arabian Gulf is known to have very high turbidity compared to other water bodies. This high turbidity is mainly due to the settling of airborne dust carried out from the surrounding desert areas. Other local activities such as land reclamation and desalination plant discharges have also increased the water turbidity in the near-coastal areas.

Turbid water could become warmer when the suspended particles absorb the heat coming from the sunlight which leads to reduction in the oxygen levels in the water which could harm the aquatic ecosystem. In addition, high turbidity affects the photosynthetic process of the plants and algae because the presence of suspended particles increases the light scattering which may lead to a decrease in the oxygen concentration in the water. Not only the suspended particles on the water surface have consequences, also particles settling in the sea bottom could have a negative effect on the aquatic organisms such as fish eggs and insect larvae by getting covered and suffocated. Sediment deposition may also accelerate the filling of shallow areas [1].

Given the impacts of water turbidity on the aquatic environment, it is important to have a better understanding of the temporal and spatial variation of water turbidity. Remote sensing technology has been demonstrated to be an efficient tool to map the physical properties of water, including turbidity.

MODIS is the most widely used sensor by the ocean color community in multiple water remote sensing applications. NASA ocean color group has already developed several water quality parameters including suspended sediment concentration, which is directly linked to water turbidity [2, 3]. Additionally, the standard MODIS products of normalized water leaving radiance have provided the basis for the most recent bio-optical algorithms.

Several well documented studies demonstrated that MODIS medium resolution bands have sufficient sensitivity for coastal water studies. Their sensitivity is 2-4 times higher than Landsat-7/ETM. This high sensitivity suggested that MODIS data could be used to assess water physical properties in smaller bodies of water such as estuaries. Maximum benefits can be achieved when remote sensing data are paired with concurrent field data. Additionally, the MODIS 250 and 500-m bands provide unprecedented capability for studying small scale features. Additionally, MODIS sensor has 9 optical bands calibrated for water application. These 9 narrow ocean color bands cover a greater dynamic range of water-related parameters for the same given condition.

2 MATERIALS AND METHODOLOGY

Degree of turbidity level in water affect the quantity of light that enter into the water column, which in turn affect aquatic environment and other valuable uses [4]. From this aspect many of research focus on parameters related turbidity and degree of light penetration such as diffuse attenuation coefficient at 490 nm (K490) and euphotic depth. The diffuse attenuation coefficient at 490 nm (K490) consider as a good indicator of water clarity. The diffuse attenuation coefficient at 490 nm shows penetration of visible light in the water column through the blue to green area of the spectrum. Moreover, the degree of light intensity at 490 nm which attenuated with depth is represented with the K490 value. [5] In this paper the K490 will be used to evaluate turbidity along Abu Dhabi coastline.

The Kd calculation algorithm proposed by Austin and Petzold (1981) [6] was used in this study. This algorithm is based on a simple linear regression approach applied on a sample of spectral irradiance and radiance profiles (eq. 1).

$$K(490) = K_w(490) + A\left[\frac{L_w(\lambda_1)}{L_w(\lambda_2)}\right]^B \qquad \text{eq. 1}$$

where Kw(490) is the diffuse attenuation coefficient for pure water, LW(λ1) and LW(λ2) are water-leaving radiances at wavelengths λ1 and λ2, and A and B are coefficients derived from linear regression analysis of the logarithmic expression of eq. 1.

2.1 Study Site

In this project a study area 30x30 km^2 along Abu Dhabi coastline was chosen. To have a better estimate for the spatial and temporal difference two subareas of 12 x 12 km^2 each within the actual study area was selected.

2.2 Data set

In this paper Giovanni tool was used to obtain Ten years of monthly satellite data for the diffuse attenuation coefficient at 490 nm (K490), acquired by the Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) instruments with 4 km resolution. Giovanni tool is a web-based application developed by the NASA GES DISC (Goddard Earth Sciences Data and Information Services Center). The obtained data is used to produce maps for the average diffuse attenuation coefficient over a 10-year period.. The HDF files for the acquired K490 were used to produce maps for the two subareas (B) and (C). To estimate the seasonal variation in these two subareas, September (summer) and January (winter) maps generated from 2009 to 2011 was analysed.

3 ANALYSES

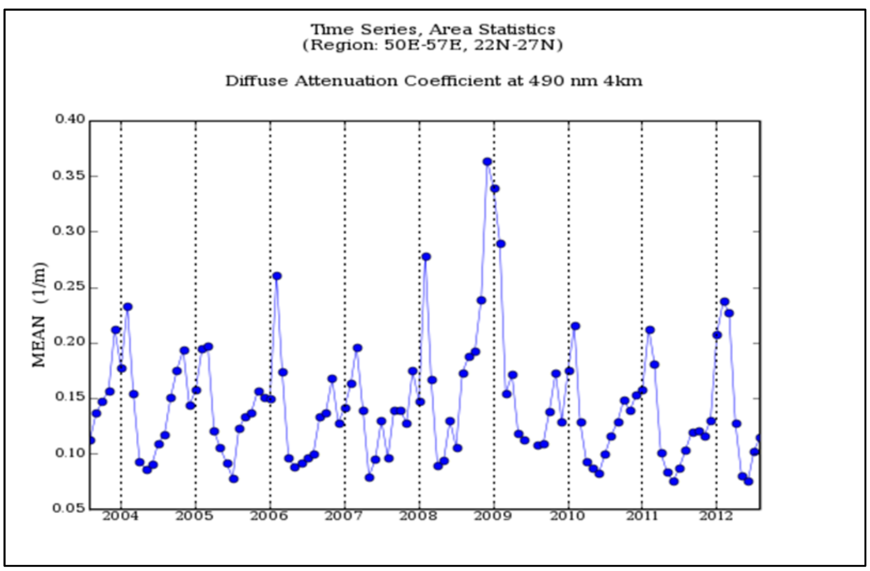

Fig.2. the diffuse attenuation coefficient at 490nm (K490), over the UAE coastal area (Aug 2003- Aug 2012).

The time series graph presented in figure 2 shows the seasonality of the diffuse attenuation coefficient at 490nm (K490) over the UAE coastal area from August 2003 to Aug 2012. It shows a clear seasonality cycle with minimum value of K (490) of 0.07 m^{-1} and peak value 0.35 m^{-1} observed in 2009. Mostly minimum values of k(490) are observed in the winter season. In the UAE almost the cooler month is January and the beginning of September has higher temperature. To monitor the effect of temperature change in k(490) values of the months of January and September from year (2009-2011) was observed.

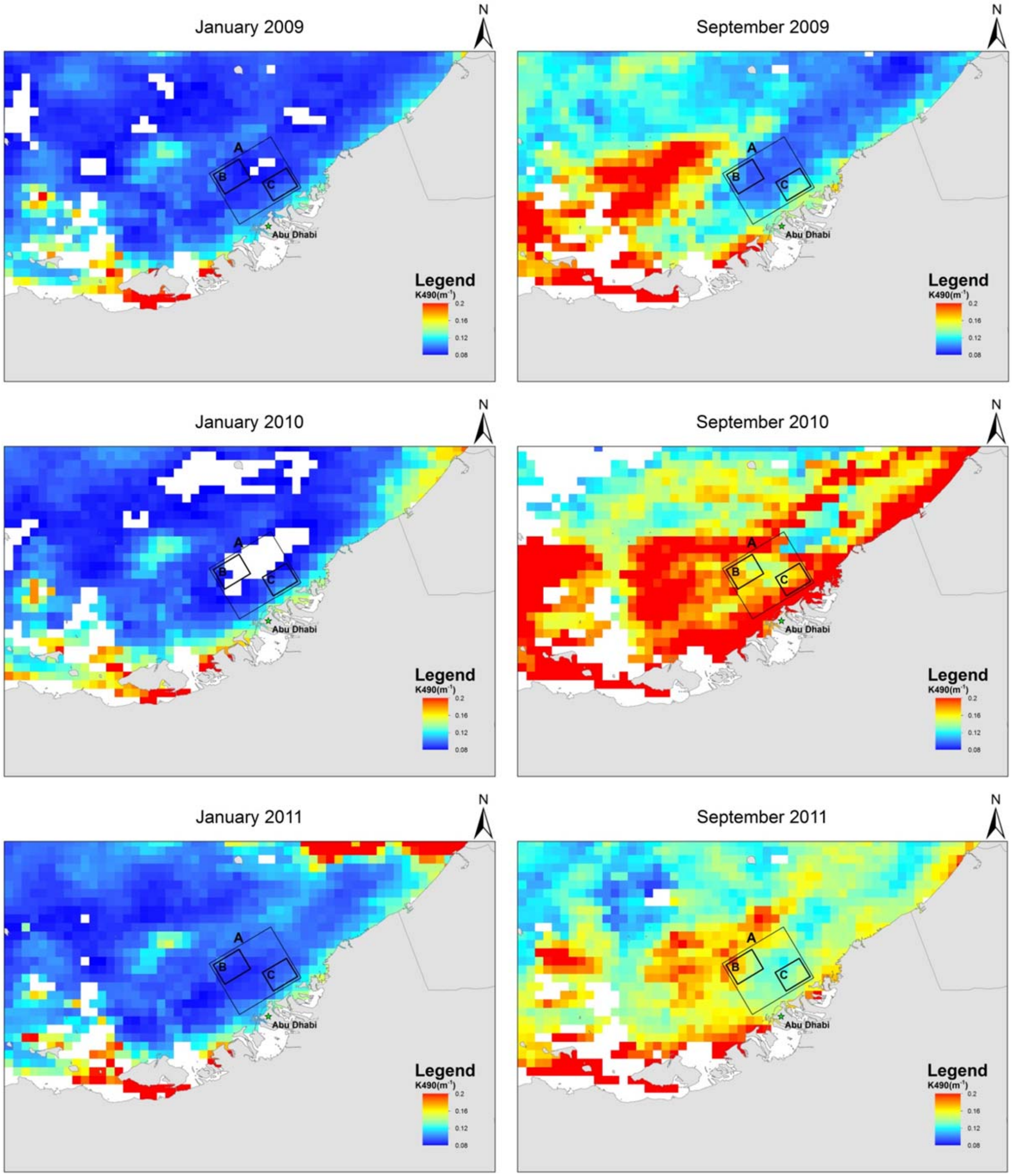

Fig.3. Seasonal and spatial variation of water turbidity in Abu Dhabi coastal areas between 2009 and 2011

4 CONCLUSION

Developing satellite-based tool based on K (490) model to produce daily assessment of water turbidity in UAE coastal areas will improve our understanding of its temporal and spatial variability. The analysis of the months of January and September has shown that low k(490) values (low turbidity) are generally observed during winter seasons (0.018 - 0.12 m^{-1}) and higher values (high turbidity) are generally observed during summer seasons (0.12 - 0.2 m^{-1}). The kd index is widely used as indictor for the amount of light penetration into the water column. Based on the obtained results, light penetration could be 15m or less in summer while in winter it may reach 30m given the low turbidity.

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