



# Setting of Cloud Albedo in the Atmospheric Correction Procedure to Generate the Ocean Colour Data Products from OCM-2

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Received: 11 March 2014 / Accepted: 29 September 2014 / Published online: 20 January 2015  
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**Abstract** Cloud masking is one of the primary and important steps in the atmospheric correction procedure in particular to coastal ocean waters. Cloud masking for ocean colour data processing is based on the assumption that the water reflectance is close to zero in the near-infrared (NIR). This is valid over the open ocean, but coastal waters may have a higher NIR reflectance due to the presence of suspended sediment concentration and non-maritime aerosols. As the result, more scattering is observed in the water leaving radiance and hence sometimes the cloud-free pixels are also classified as clouds, leading to data loss. In this present study, we have analysed cloud albedo value for masking the clouds using the default cloud masking threshold (0.027) set for processing the global ocean colour sensors like SeaWiFS and MODIS and now OCM-2 in the SeaWiFS Data Analysis System (SeaDAS). The default cloud masking value of SeaDAS over masks the clouds and sometimes the turbid coastal water pixels are also getting masked when implemented over the COM-2 imageries. Hence, an exercise has been carried out to set the cloud albedo value for OCM-2 sensor and the albedo values were tested with the lower and higher values ranging from 0.015 to 5.0 as the threshold and from the analysis it is found that 0.07 is the optimum value for Ocean Colour Monitor-2 (OCM-2) sensor for masking the clouds. Using this threshold, maximum

valid ocean pixels are achieved compared to the default cloud albedo mask with the value 0.027. This has been checked with both the Local Area Coverage (LAC) and Global Area Coverage (GAC) products of OCM-2 and the results were also compared with the MODIS data. Hence, it is recommended that 0.07 is the optimum cloud masking threshold for OCM-2 sensor.

**Keywords** Oceansat-2 OCM · Atmospheric correction · Cloud albedo

## 8Introduction

The Indian Space Research Organisation launched its first GLOBAL ocean colour sensor “Ocean Colour Monitor” on board Oceansat-2 satellite on 23rd September 2009. Since then the ocean colour data with 1 km resolution is available for the global community for free of cost. The purpose of the OCEANSAT-2, Ocean Colour Monitor-2(OCM-2) mission is to provide continuity to the OCEANSAT-1, OCM-1mission and to obtain quantitative information on the ocean colour variables e.g., (i) chlorophyll-*a* concentration, (ii) vertical diffuse attenuation of the light ( $K_d$ ) characterized at 490-nm, (iii) suspended matter concentration in coastal waters etc. As a part of ocean colour data processing, NASA has incorporated all the specifications of the OCM-2 sensor in the global processing software called SeaDAS.

Atmospheric correction of ocean colour imagery is one of the most crucial and important procedure for retrieving the ocean colour data products from the ocean colour sensors. The main objective of ocean colour remote sensing is to derive the ocean water-leaving radiance spectra by accurately removing the atmospheric

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and surface effects. At satellite altitude ~90 % of sensor-measured signal over the ocean comes from the atmosphere and ocean surface. Hence, it is crucial to have accurate atmospheric correction procedure that requires sensor calibrations, as 0.5 % error in atmospheric correction or calibration corresponds to possibility of ~5 % error in the derived ocean water leaving radiance (Wang and Shi 2006). In this study, the atmospheric correction procedure implemented for processing of OCM-2 based on the single scattering albedo approximation (Gordon and Wang 1994), the Rayleigh scattering by air molecules are computed in the absence of aerosol, which is considered separately. The aerosol scattering contribution is computed in the absence of molecules (Gordon and Morel 1983). In this processing scheme, the coupling of the scattering by aerosol molecules and selection of various types of aerosols are addressed. The atmospheric correction procedure for OCM-2 is similar to the atmospheric correction procedure implemented for SeaWiFS/MODIS as: Rayleigh radiance is computed from the Rayleigh lookup tables prepared based the vector radiative transfer theory.

### OCM-2 Instrument

OCM-2 instrument is designed to measure the spectral variability of the water leaving radiance that is related to concentration of phytoplankton pigments, suspended matter and coloured dissolved organic matter in coastal and ocean waters, and the characterize the atmospheric aerosols. OCEANSAT-2, OCM (OCM-2) is identical to OCM-1, except minor spectral shift in band 6 and 7. In OCM-1, band –6 centered at 670 nm is shifted to 620-nm in OCM-2 for better quantification of suspended sediments and band 7 centered at 765-nm is shifted to 740-nm to avoid oxygen absorption.

### Materials and Methods

#### Atmospheric Correction and Retrieval Strategy

The geophysical retrieval procedures is applied only to cloud free pixels over open-ocean and coastal waters that are not affected by sun glint (Shanmugam 2012). If a cloud mask, land mask or sun glint mask are not set for a given pixel, which is considered clear ocean pixel to retrieve geophysical parameter. To perform atmospheric correction other ancillary data sets such total ozone amount and sea surface wind is also used. The output of the atmospheric correction is water-leaving reflectance transformed to remote sensing reflectance

( $R_{rs}$ ), which is used as an input for the bio-optical algorithms to estimate the chlorophyll concentrations.

### Current Cloud Masking in OCM

The spectral composition of the visible region (400–700 nm) changes based on the in-water constituents concentration. However, in the near infrared (NIR) region, water strongly absorbs which has uniformly less albedo value. Clouds, in contrast, have a wide spectral variability from the visible to NIR regions in the reflectivity value measured at the top of the atmosphere (TOA) or at the sensor level. Hence, an albedo based cloud masking approach, which makes use of band 8, i.e., 865 nm has been adopted for OCM sensor (Chauhan and Nagamani 2007). The albedo at 865-nm, i.e.,  $\alpha_{865}$  is calculated as mentioned below:

$$\alpha_{865} = [L_t(865)/(t(865, 0)L_i(865))] * 100\% \quad (1)$$

Where,  $L_t(865)$  is the total radiance measured by the sensor in band 8, at 865-nm,  $L_i(865)$  is the incident light at 865-nm,  $t(865, \theta)$  is the diffuse transmittance between the surface and the sensor at 865-nm, and  $\theta$  is the satellite zenith angle (Eckstein and Simpson 1981). The diffuse transmittance between the surface and sensor at 865 nm is calculated as

$$t(865, q) = \exp[-(0.5\tau_r + \tau_{oz})/\cos q] \quad (2)$$

Where,  $\tau_r$  is the Rayleigh optical thickness and  $\tau_{oz}$  is the ozone optical thicknesses at 865-nm. The incident light at 865-nm is computed as

$$L_i(865) = t(865, \theta_0) F_0 \quad (3)$$

Where  $F_0$  is the extra-terrestrial solar irradiance at 865-nm and  $\theta_0$  is the solar zenith angle. The diffuse transmittance between the sun and the ocean surface at 865-nm is compute as;

$$t(865, 0_0) = \exp[-(0.5\tau_r + \tau_{oz})/\cos q_0] \quad (4)$$

It is found that the pixel in the 865-nm band having albedo greater than 1.1 % would be masked successfully for clouds, thin clouds and haze. This threshold value is also found to be effective for masking land and sun glint affected pixels.

### Cloud Masking Approach for Other Ocean Colour Sensors

Other contemporary global ocean colour sensors like Sea viewing Wide Field Sensor (SeaWiFS) and

Moderate Imaging Spectro Radiometer (MODIS) have a standard cloud masking procedures. These procedures are based on the cloud test on a Rayleigh-subtracted quantity, such as surface + aerosol reflectance at 865 nm. A threshold on this quasi-surface reflectance field,  $\rho_s(865)$ , of 0.027 (2.7 %) has been found to yield very similar results to the reprocessing #3 (Robinson et al. 2000) algorithm at moderate solar and viewing geometries, while still allowing high solar and view angle observations of apparently clear ocean pixels to pass through unmasked. Standard Algorithm implemented (tuned for reprocessing #4) for SeaWiFS sensor for generating the Geophysical data products is given below:

$$\text{albedo} = 100 * Lt(865) * t_0^2 / F_0 / m_0 \tag{5}$$

if (albedo > 1.045) then cloud

The current (latest) cloud masking algorithm for the SeaWiFS is not only based on albedo but based on the row value in the 865 nm band as mentioned below:

$$r_s(865) = \pi / (F_0 * m_0 * t_0^2) * (Lt(865) / t_{oz} - Lr) \tag{6}$$

if ( $\rho_s(865) > 0.027$ ) then cloud

Where,

$Lt$  is top-of-the atmosphere radiance

$Lr$  is Rayleigh path radiance

$F_0$  is solar irradiance (day of year corrected)

$t_0$  are Rayleigh diffuse transmittance, surface to sensor and sun to surface

$t_{oz}$  (oz) is ozone transmittance (both directions)

$\mu_0$  is cosine of the solar zenith angle

The same procedure has been adopted for the other contemporary ocean colour sensors like MODIS and MERIS for masking the clouds using SeaDAS. This current threshold of 0.027 is used till date for masking the clouds even in the 9th reprocessing scheme for SeaWiFS and MDOIS sensors.

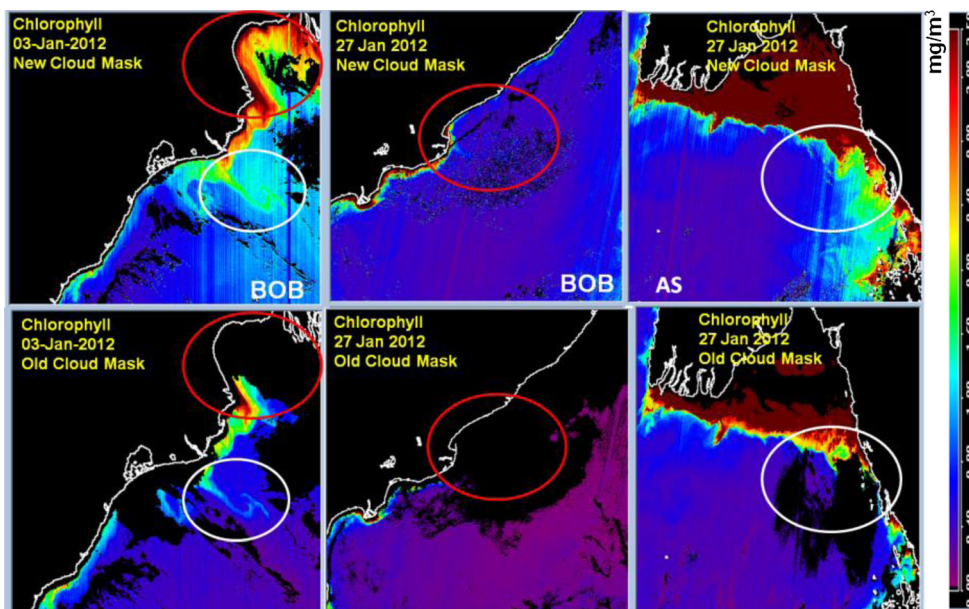
### Limitations and Need for the Refinement of Cloud Mask

In ocean Colour processing, the cloud masking is essential and effectively cloud mask to generate level-2 product  $\rho_s(865)$ , of 0.027 (2.7 %) is found to be effective. The assumption of lower values in the near-infrared (NIR) water-leaving radiance is no longer valid (Ruddick et al. 2000; Hu et al. 2000; Shanmugam 2012). The MODIS cloud masking procedure using SeaDAS with default thresholds revealed that even hazy and turbid atmosphere pixel are also masked as clouds (Hu 2009; Shanmugam 2012). However, it is observed that the threshold for cloud detection needs to be relooked in case of optically complex waters. Hence, refining existing cloud masking procedure for OCM-2 had been attempted.

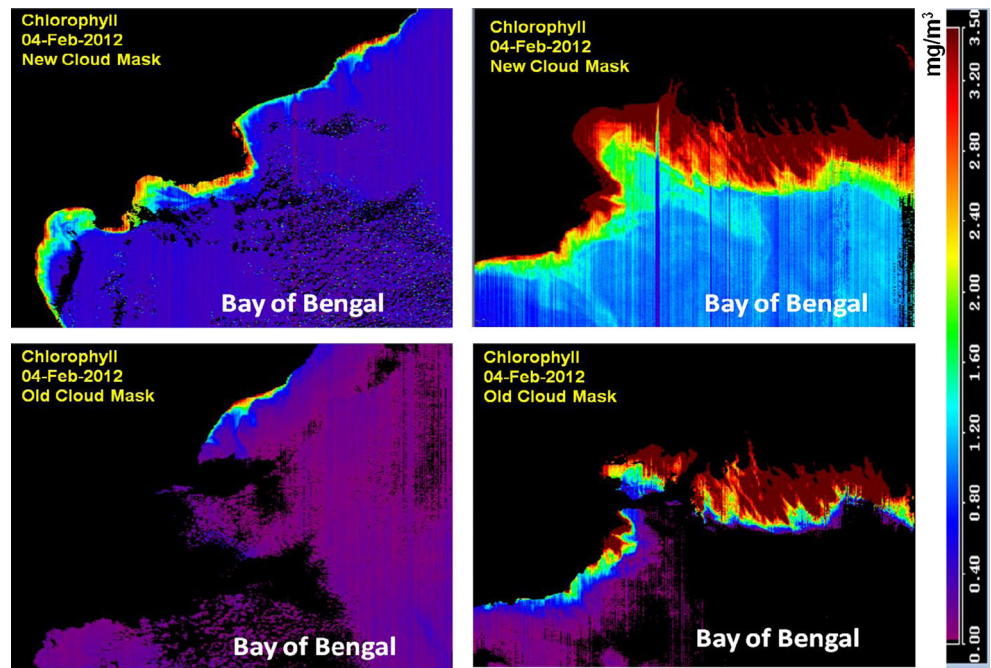
### Refined Cloud Masking for OCM-2

The 8th spectral band of OCM-2 (865 nm) is similar to SeaWiFS, therefore the same cloud masking thresholds /

**Fig. 1** Difference between the Old (down panel) and new (top panel) cloud making thresholds used in OCM-2 processing for generating the chlorophyll product

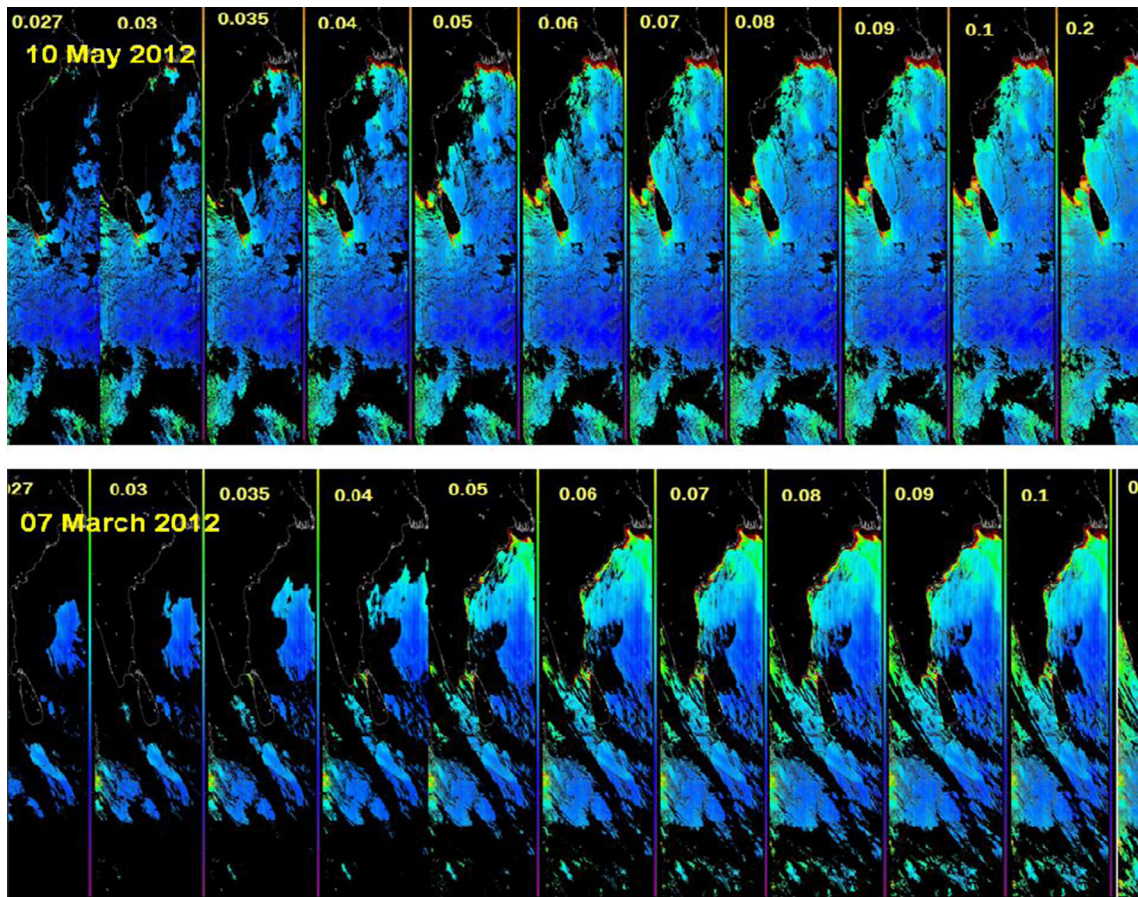


**Fig. 2** Difference between the Old (*down panel*) and new (*top panel*) cloud making thresholds used in OCM-2 processing for generating the chlorophyll product



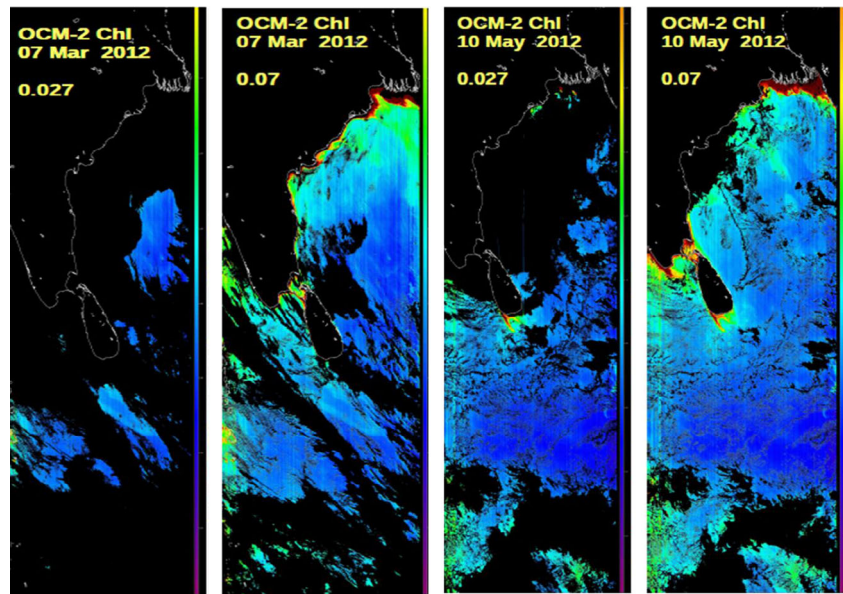
scheme was adopted for OCM-2 initially. Using the old or the standard cloud masking threshold of  $\rho_s > 0.027$

resulted in classifying and masking the cloud and haze around cloud, apart from these pixels the pixels in the



**Fig. 3** Comparison of Cloud mask thresholds using Old and New values for 10th May 2012 (*top panel*) and 7th March 2012 (*Lower Panel*) using GAC data of OCM-2

**Fig. 4** The summary of the cloud masking thresholds used in OCM-2 tested with (a) 07 March 2012 and (b) 10 May 2012 GAC (10\_14 pass) chlorophyll imagery



turbid coastal waters are also getting masked (Figs. 1 and 2) most of the time. As the result many genuine cloud free ocean pixels are masked as cloud limiting the retrieval of geophysical parameters from OCM-2 data. Further extending the cloud masking threshold on either side of 0.027 with an increment of 0.1 (0.015–0.7) were attempted, and 0.07 threshold value performed better compared to the all the values tested for the cloud masking which best discriminates and masks the cloud pixels of OCM-2 data even in the turbid coastal waters. The analysis of the threshold on OCM-2 imagery for 10th May 2012 and 7th March 2012 is shown in Fig. 3.

area compared to the previous(SeaDAS) default threshold for masking the clouds (Fig. 4). The statistical analysis (Table 1) shows that the OCM-2 data (chlorophyll-a retrieved using the new threshold) have more of number valid ocean pixels compared to the erstwhile threshold by increasing from 5 to 21 % in the 7th March 2012 data and 22 to 50 % in 10th May 2012 data as shown in Figs. 3 and 4. The statistical analysis of the cloud albedo and number of ocean valid pixels indicated that there is a consistency in the valid ocean pixels using threshold between 0.06 to 0.08 and therefore the mean value of 0.07 has been fixed as valid threshold for cloud masking for OCM-2.

**Results and Conclusion**

In this exercise, the cloud masking for OCM-2 has worked very efficiently with threshold of 0.07 by removing various atmospheric conditions such as haze and thin Cirrus clouds etc. The output data has shown a realistic spatial structure in water-leaving radiance and chlorophyll maps for the entire

**Conclusions**

The cloud masking threshold has been test on different Local Area Coverage (LAC) and Global Area Coverage (GAC) of OCM-2 and compared with the MODIS data. From the above observations it is concluded that 0.07 is the optimum for masking the cloudy pixel in OCM-2.

**Table 1** Statistical representation of the cloud thresholds

Date	07 March 2012		10 May 2012	
	0.027	0.07	0.027	0.07
Cloud threshold	0.027	0.07	0.027	0.07
OC2 chlorophyll min & max	0–5	0–5	0–5	0–5
Mean	0.7308	0.8653	0.7261	0.8323
Standard deviation	0.01643	0.3416	0.2203	0.3741
Total no. of pixel	7607160		7602188	
No. of valid ocean pixels	379666 (4.9909 %)	1621206 (21.3116 %)	1654720 (21.7664 %)	3115420 (40.9806 %)
No. of masked pixel	7227494 (95.009)	5985954 (78.6884 %)	5947468 (78.2336 %)	4486768 (59.0194 %)

**Acknowledgments** This work is carried out under NCP project under ISRO-GBP program of NRSC. The authors would like to express their sincere thanks to SeaDAS package and ocean colour web for free access their support.

The authors express their sincere thanks to the SeaDAS package for facilitating to process OCM-2 data and ISRO for funding the project to carry out this work.

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