Inter-comparison of atmospheric correction algorithms for MODIS: Evaluation with emphasis on coastal waters

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Objective
Accurate atmospheric correction (AC) is a prerequisite for quantitative ocean color remote sensing and remains a challenge above optically complex coastal waters due to the difficulty of separating the atmospheric path radiance from the water-leaving radiance. Atmospheric correction algorithms have been extensively validated alone but rarely been inter-compared. The performance of six atmospheric correction methods were compared for the Terra and Aqua Moderate Resolution Imaging Spectroradiometers using shipborne above water reflectance measurements.

Algorithms (1) The standard near-infrared (NIR) AC [Ref. 1], (2) the shortwave-infrared (SWIR) AC [Ref. 2], (3) the NIR-SWIR switching AC method [Ref. 3] all three (1-3) as implemented in SeaDAS version 6.1 (4) the MUMM turbid water plugin [Ref. 4] (5) CSIRO’s Artificial Neural Network AC [Ref. 5] and (6) the MOD09 land surface AC algorithm [Ref. 6].

In-situ data
In-situ above-water reflectance data were collected by MUMM, GKSS and CSIRO during various cruises between 2001 and 2008 (Tab. 1). In total 837 reflectance spectra were obtained during these campaigns and combined into a data base, which was subsequently used for match-up analysis. MUMM used a system of three TRISOS-RAMSES hyperspectral spectro-radiometers to simultaneously collect above-water measurements of the down-welling irradiance (E_d), the upwelling radiance (L_up), and the sky radiance (L_sky). Conversion into reflectance then followed the REVAMP protocols. CSIRO measured the above water reflectance with only one TRISOS radiance sensor from subsequent L_sky, L_up, measurements during absolute clear sky conditions along with indirect E_d measurements obtained from radiance measurements of a Spectralon 99% reflectance panel. Further processing was in accordance with MUMM, GKSS deployed the SIMBADIA hand-held field radiometer to obtain above water reflectance from subsequent L_up and sun radiance L_sky measurements.

Match-up analysis
The accuracy of the atmospheric correction algorithms was assessed by match-up analysis, extracting 3x3 satellite pixels from the processed MODIS images at the location of the in-situ measurements and comparing the median with the in-situ reflectance spectra within a maximum time window (T) of 3 hours to the satellite overpasses. A valid match-up required the location difference to be less than 0.01 degree in both latitude and longitude dimensions. To enable algorithm inter-comparison only a single match-up data set (i.e. the same satellite pass) was extracted from each cruise, having a common set of flags for quality control and exclusion of erroneous and out-of-range pixels. In detail, we flagged land, cloud/ice, or high sun glint in addition to high sun angles above 75 degrees and observer zenith angles above 60 degrees using the Level 2 flags provided by SeaDAS. A valid match-up required all nine pixels of the match-up area to be valid (unflagged).

Results
• ANN showed distinctly better results at 412.5 nm (RAPE 26%) than the algorithms that extrapolate atmospheric correction from the NIR or SWIR to the shorter wavelengths.
• Standard NIR correction showed second best performance and was the most accurate SeaDAS v6.1 algorithm compared in this study.
• Least accurate results were obtained with the native SWIR correction that produced noisy outputs due to the low signal-to-noise of the SWIR bands.
• However good results were obtained from SWIR on a case by case basis and above the recommended turbidity threshold.
• Switching from native SWIR to NISW reduced the overall retrieval errors.
• MOD09 AC algorithm showed relatively good agreement with the in-situ reflectance data analyzed in this study even though it was developed for land applications.
• Unphysical negative reflectance data were retrieved by all algorithms except for Aqua NIR within T11 hour and the ANN algorithm.
• Future inter-comparison studies should include synthetic data, which would allow a more comprehensive performance assessment by testing for specific and atmospheric conditions algorithm limitations.
• A free copy of the ANN code can be obtained from the principle author.

REFERENCES

This research was funded by the CSIRO Wealth from Oceans Flagship and the Great Barrier Reef Marine Park Authority through the Reef Rescue Marine Science Program and the NICTAS-Marine Ecosystems Research Programme RECOG(ME) project (P1015000). We are grateful to Prof. Doerffer for providing the MUMM turbid water plugin code. The National Oceanic Development Group and the Ocean Science Processing Group at NASA GSFC are acknowledged for development, support and distribution of the SeaDAS software, and the NASA LADS Web for distributing the MOD09L1 data.

ACKNOWLEDGEMENTS
A principal contribution from the Remote Sensing Group, CSIRO Land and Water, Coastal Research Unit and the Marine and Coastal Observation Branch, CSIRO, was received in the form of software and in-kind support.
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ABSTRACT

This study aims at evaluating the performance of six atmospheric correction algorithms for the Moderate Resolution Imaging Spectroradiometer (MODIS) on board the Terra (EOS AM) and Aqua (EOS PM) satellites. Algorithm performance was assessed by match-up analysis, comparing satellite estimates of spectral above water remote sensing reflectance with in-situ measured reflectance data. The in-situ measurements were collected by MUMM, GKSS and CSIRO, predominately in European and Australian coastal waters, during various field campaigns between 2001 and 2008. In detail, we compared three SeaDAS (v6.1) implemented atmospheric correction methods – the standard near-infrared (NIR) correction, the shortwave-infrared (SWIR) algorithm and the NIR-SWIR switching algorithm, along with the MUMM turbid water plug-in and CSIRO’s Artificial Neural Network (ANN) approach. Further, we included the MOD09 land surface reflectance algorithm to evaluate its performance for coastal application. All algorithms were compared using the same match-up data set by applying a common set of flags for quality control and exclusion of erroneous and out-of-range pixels. Several band averaged and spectrally resolved error statistics were computed at different time steps (±1-3 h) to the satellite over passes including different match-up area sizes – for Terra/Aqua combined and for each sensor separately. Aqua performed overall better than Terra using the SWIR, NIR-SWIR, MOD09 and MUMM algorithms, whereas both sensors showed similar good results from the application of the NIR and ANN methods. Overall best performance was obtained with the neural network approach, followed by the standard NIR correction. Least accurate results were found with native SWIR processing, which resulted in noisy outputs due to the low signal-to-noise of the SWIR bands and improper filtering for below threshold turbidity indices. Nevertheless, good results were obtained from SWIR on a case by case basis. Switching from native SWIR to NIR-SWIR reduced the overall retrieval errors. More detailed results will be presented.