Simultaneous retrieval of aerosol optical thickness and chlorophyll concentration from multi-wavelength measurement over East China Sea

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AGU Fall Meeting, San Francisco, December 2016

Abstract
A flexible inversion algorithm is proposed for simultaneously retrieving aerosol optical thickness (AOT) and surface chlorophyll-a (Chl) concentration from multi-wavelength observations over the East China Sea. This algorithm, based on radiative transfer computation performed by an accurate coupled atmosphere-ocean model with a comprehensive bio-optical ocean module. Then, a full-polarization simultaneous optimization approximation approach is used to retrieve AOT and Chl. For AOT retrieval, a global three-dimensional spatial radiation transport aerosol model (SPRINT-AER) is used as the prior constraint to increase the retrieval accuracy of aerosol. To investigate the algorithm’s capability, the experimental system is conducted using simulated radiance data to demonstrate that the relative errors in simultaneously determining AOT and Chl can be mostly controlled to within 10% using multi-wavelength and angle covering in out of sunglint. Furthermore, the inversion results are assessed using the actual satellite observation data obtained from Cloud and Aerosol (CAG) Measurements program (AERONET) aerosol and ocean color (OC) products over East China Sea. Both the retrieved AOT and Chl compare favorably to the reported AERONET values, particularly when using the CASE-2 ocean module in turbid water, even when the retrieval is performed in the presence of high wind speed and sunglint. Finally, the CASI and MODIS images are used to jointly retrieve the spatial distribution of AOT and Chl in comparison to the MODIS AOT and OC products.

Background
Aerosols are considered to exert considerable effects on global and regional climate change. Besides, it is also important to retrieve the optical properties of aerosols to improve the remote sensing of ocean color.

In the conventional ocean color remote sensing algorithms, the atmosphere and ocean systems are decoupled in two independent steps: atmospheric correction procedures to remove the influence of atmospheric and retrieval of the surface chlorophyll-a (Chl) concentration.

Another method using the direct inversion algorithm, that is simultaneous retrieval of atmospheric and oceanic parameters, may be also a feasible way of improving the prevailing schemes using the radiative transfer model to minimize the simulation output and measured uncertainties.

Research Objective
To develop a comprehensive bio-optical ocean module and coupled into a radiative transfer model in the atmosphere-ocean system.

To develop a flexible inversion algorithm to simultaneously retrieve the atmosphere and oceanic optical parameters.

RT Model
Radiative Transfer Scheme: Point (Ohtani et al., 2010)

Bio-optical ocean module

Aerosol optical properties including the influence of temperature and salinity

New Chlorophyll-inherent Optical Properties database

CASE-2 water including yellow sand and Color Dissolved Organic Matter (CDOM)

Sea Water

Sea Salinity

AOT

Chl

Surface

Absorption

Scattering

Absorption

Scattering

Function

Phase function

Figure 1. Flow chart of retrieval algorithm.

Optimization method

Validation (GOSAT/CAI)

MODIS Image

CAI Image

Figure 2. Comparison of MODIS products (a) and (b) and CAI retrieval results using this algorithm (c) over East China Sea.

Table 1. Comparison of TANSO-CAI AOT (b) and AOT simultaneously retrieved from MODIS

Figure 3. Simulation of simultaneous retrieval of AOTs for fine, sea salt, and dust particles at 550 nm, and chlorophyll-a concentration with input values. The blue line shows the dilution value 10% smaller or larger than the input values.

Figure 4. Comparison of satellite simultaneously retrieved AOT and Chl (mg/m³) from CAI with AERONET observations at the Ieodo (1550 nm, AOT) and Chl (bands: 750 nm, AOT-d, and Chl) sites using CASE 2 water module. The simultaneous retrieved results of AOT and Chl are shown in units of

Figure 5. Spatial distribution of simultaneously retrieved total aerosol optical thickness (a) and chlorophyll-a concentration (b) using CAI imagery on 15 March 2012 over East China Sea.

Figure 6. As in Fig. 4, but for retrieval using MODIS Aqua data and CASE 1 model.

Figure 7. Similar to Fig. 6 but for retrieval using CASE 2 ocean module.

More results

Validation (MODIS/Aqua)

Figure 8. Similar to Fig. 7 but for the retrieval in UM_SEAIRSIMS site.

Conclusions

A flexible full-physics retrieval algorithm was developed to simultaneously determine AOT and Chl based on multi-wavelength measurements with one-step.

The inversion algorithm uses an accurate radiative transfer model to simulate the forward radiation process in the atmosphere-ocean system based on an updated bio-optical module.

The inversion results are compared using the CASE-2 ocean module and MODIS retrievals with respect to the AERONET aerosol and ocean color (OC) products. Both the retrieval results compare favorably to the reported AERONET values, particularly when using the CASE-2 ocean module in turbid water.

Development of an acceleration algorithm using look-up-table or network method is also a part of our future work.

Authors

Shi, C., T. Nakajima, and M. Hashimoto (2016), Simultaneous retrieval of aerosol optical thickness and chlorophyll-a concentration (b) using CAI imagery on 15 March 2012 over East China Sea.


Main references