RETRIEVAL OF WATER CONSTITUENTS FROM MULTIPLE EARTH OBSERVATION SENSORS IN COASTAL AND INLAND WATER ENVIRONMENTS

Thomas Heege(1), Viacheslav Kiselev(1), Daniel Odermatt(2)

(1) EOMAP GmbH & Co. KG, Sonderflughafen Oberpfaffenhofen, Geb. 319
D-82205 Gilching (Germany), Email: heege(kiselev)@eomap.de
(2)Remote Sensing Laboratories (RSL), Dept. of Geography, University of Zurich, Winterthurerstr. 190,
CH-8057 Zurich (Switzerland), Email: dodermat@geo.unizh.ch

1. INTRODUCTION

Applied water quality monitoring of coastal zones or aquatic systems, such as rivers and lakes, requires processing of multiple images with variable temporal and spatial resolution. Compatible results in this case can be obtained by sensor-independent processing techniques. The physics-based, flexible, modular image processing system MIP can ensure standardized product outputs for a variety of satellite sensors. The algorithms and the processing chain of this system are automatically adapted to the sensor parameters, as well as to the regional specific inherent optical properties (SIOP) of the aquatic or coastal environment under study.

2. METHODS

The algorithms of MIP [1,2] are based on a coupled retrieval of atmospheric and water properties providing for the best fit of measured and modeled radiances in all selected spectral channels. The number of retrieved water species and final products depend on the spectral and radiometric resolution of the sensor; at the very least, suspended matter and atmospheric aerosol optical depth are retrieved. With higher number of channels, the concentrations of absorbing water constituents such as colored dissolved organic material (CDOM) and phytoplankton pigments (i.e. chlorophyll) can be obtained.

The coupled retrieval of water and atmospheric parameters in MIP is performed using the radiative transfer data base, built for a coupled, plane-parallel atmosphere-water model with finite element method program (FEM) [3] as a solver and the Gordon-formula modified by Albert [4]. The retrieved values give the minimum of the functional:

$$\min_{\tau} G(\tau) = \min_{\tau} \sum_{i=1}^{N_{ch}} w_i \left\{ L_i^{(0)} - L_i\left[\tau, \vec{c}(\tau)\right] \right\}^2 \tag{1}$$

where $L_i^{(0)}$ is the measured radiance in the i-th channel, N_{ch} is the number of channels, τ is the atmospheric optical width, w_i is the user defined weight of the i-th channel, $L_i[\tau, \vec{c}(\tau)]$ is the modelled radiance at sensor level, $\vec{c}(\tau)$ is the vector of water constituent concentrations (chlorophyll, total suspended matter, yellow substance) retrieved from remote sensing data at fixed value of τ. This vector is calculated by minimizing the next equation:

$$\min_{\vec{c}} H(\vec{c}, \tau) = \min_{\vec{c}} \sum_{i=1}^{N_{ch}} \tilde{w}_i \left\{ \tilde{R}_i\left(I_i^{(0)}, \tau\right) - R_i(\vec{c}) \right\}^2 + \sum_{j=1}^{3} \lambda_j \left(c_j - c_j^{(0)}\right)^2 \tag{2}$$

where $\tilde{R}_i(L_s^{(0)}, \tau)$ is the underwater irradiance reflectance, provided for the given τ at the sensor level radiance $L_i^{(0)}$ at sensor level, $R_i(\vec{c})$ is the subsurface irradiance reflectance, calculated for the species concentrations $\vec{c}$ according to the formula:

$$R(\vec{c}) = f \frac{\sum_{j=1}^{3} c_j b_j^* + b_w}{\sum_{j=1}^{3} c_j a_j^* + \sum_{j=1}^{3} c_j b_j^* + a_w + b_w}$$

$$R(\vec{c}) = Ap_1(1 + p_2x + p_3x^2 + p_4x^3)$$
$$x = \frac{\sum_{j=1}^{3} c_j b_j^* + b_w}{\sum_{j=1}^{3} c_j a_j^* + \sum_{j=1}^{3} c_j b_j^* + a_w + b_w} \quad (3)$$

where a_j^* and b_j^* are specific absorption and backscattering coefficients of water constituents, a_w and b_w are absorption and backscattering coefficients of water, and A is a sun position dependent parameter. The values of coefficients p_i are presented in [4].

The second additive in Eq. 2 accounts for the regularisation of the problem, i.e. for the increase of its stability in case the minimum of the first additive is not clearly expressed. $c_j^{(0)}$ are initial concentrations of water constituents, which are characteristic for the considered region, λ_j regulates the weighting of the regularisation, which has to be low enough not to significantly influence the position of the minimum of the functional as a whole when the first additive has a sharp minimum.

3. APPLICATION

The MIP system can process MODIS (250m, 500m and 1km resolution), MERIS, SPOT3+4, Landsat ETM7, ASTER, and QuickBird scenes, and has been applied in various different situations for lakes (e.g. Lake Sevan, Lake Constance [5,6]), rivers (e.g. Mekong delta and Ems River) and coastal environments (Australia, Vietnam, Chile, and Africa). Key aspects in robust processing are radiometric sensor calibration, specific optical properties of the monitored environments, and the aerosol optical properties. The number of retrieved parameters and the product quality depend on the sensor characteristics and observation conditions (e.g. prevalence of sun glitter, turbidity). The role of the dominant influencing factors, with an emphasis on sensor calibration in different applications, are discussed for specific cases.

11. REFERENCES

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