Biogeochemistry of the Scheldt Estuary and Plume

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ABSTRACT

Water quality variables were examined in the Scheldt estuary and plume, using CASI-2 (Compact airborne Spectrographic Imager) hyperspectral sensor and in situ bio-optical observations. Multiple regression approach has been used to derive correlation between classical ground truth measurements and the rich information provided by the numerous CASI spectral bands. From these relations, some synoptic maps of biogeochemical parameters could be derived in the Scheldt estuary and plume, as coloured dissolved organic matter (CDOM); dissolved inorganic carbon (DIC); pressure $CO_2$and dissolved organic carbon (DOC).

INTRODUCTION

Estuaries are obligate pathways for the transfer of dissolved and particulate material from the continent to the marine system. The Scheldt basin (Belgium-Netherlands coastal zone) covers one of the most populated and industrialised areas of Europe and its tributaries drain an area of about 21,860 km^2. The amounts of nutrients discharged by the Scheldt increased considerably during the past 20 years. Due to the dilution and metabolic processes of the downstream river flow in the estuary, an important variability of several parameters can be observed amongst which phytoplankton species and concentration, particulate organic matter, colour dissolved organic matter and suspended matter. In the present days, researches on the functioning of estuarine and coastal ecosystems are based on highly time consuming, costly sea campaigns and laboratory analyses. Although optical spaceborne remote sensing already proved useful in such coastal ecosystems studies, hyperspectroscopy opened a new dimension by allowing improved distinction of various biogeochemical compounds through characteristic spectral signature identification. The goal of this research is to explore the potential of CASI airborne hyperspectroscopy in retrieving some of the biogeochemical parameters of interest in the Schedlt estuary and plume.

MATERIALS AND METHODS

On the 12 of September 2002, an airborne campaign using 48 CASI spectral bands covered part of the Scheldt estuary from altitude of 10,000 m, in five different flight lines and with spatial resolution of 4 meters (see Figure 1 and 2 A). During the same day, a 12 sampling stations in-situ survey was realised in order to cover as quickly as possible the wide range of water quality encountered from the mouth of the estuary to the outer limit of the plume. The numerous parameters and reflected spectrum measured in each station were used for further remote sensing analysis, as well as to complete the interpretation of the observed environmental processes. The image processing included radiometrical, atmospherical (ATCOR), geometrical and gain and offset (EFFORT) corrections. To derive Chlorophyl a and suspended sediments, many classical algorithms were tested. However, these classical algorithms did not allow to establish correlation with the CASI data, due to lack of pics in the spectra mainly in the wavelengths 0.65-0.73 µm. This problem is well known in turbulent case II water, the high sediment concentrations causing high reflectance in most of those wavelengths. Multiple regression developed by Hirtle and Arencz (2003) was used as statistical exploration of the large hyperspectral bands. The best correlation was used for mapping related parameters

Figure 1: Scheldt test site: CASI five flight lines, the triangles represent the location of 12 in situ survey stations.

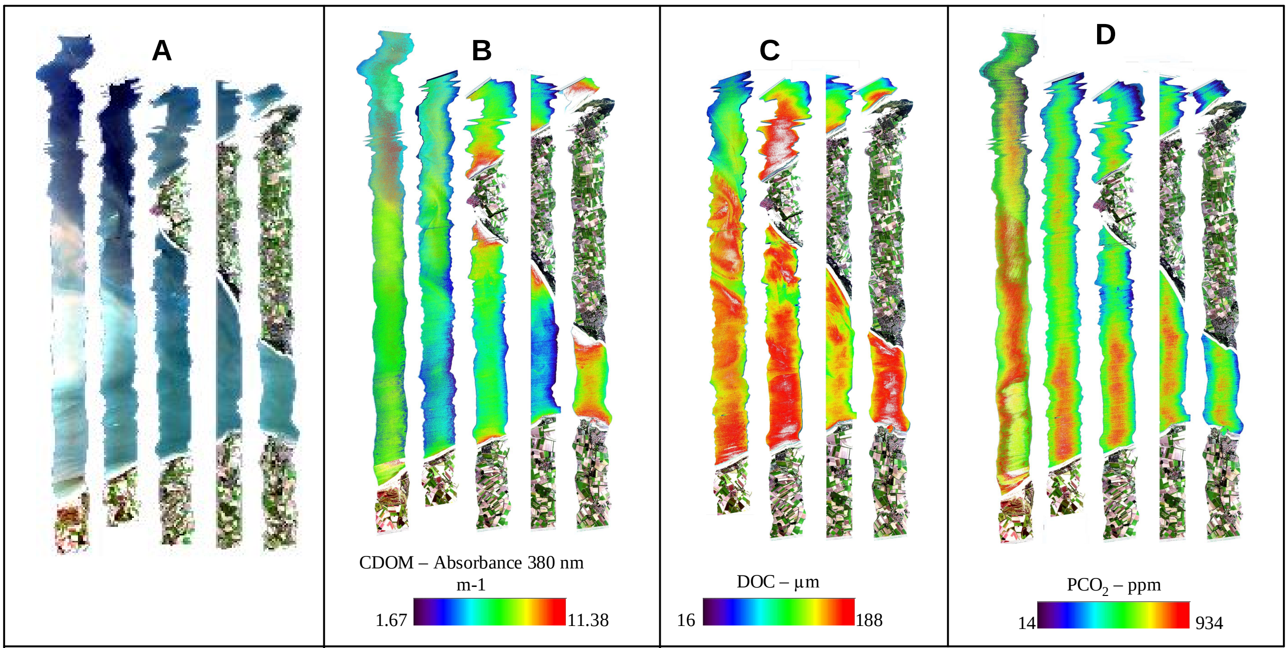
RESULTS AND DISCUSSIONS

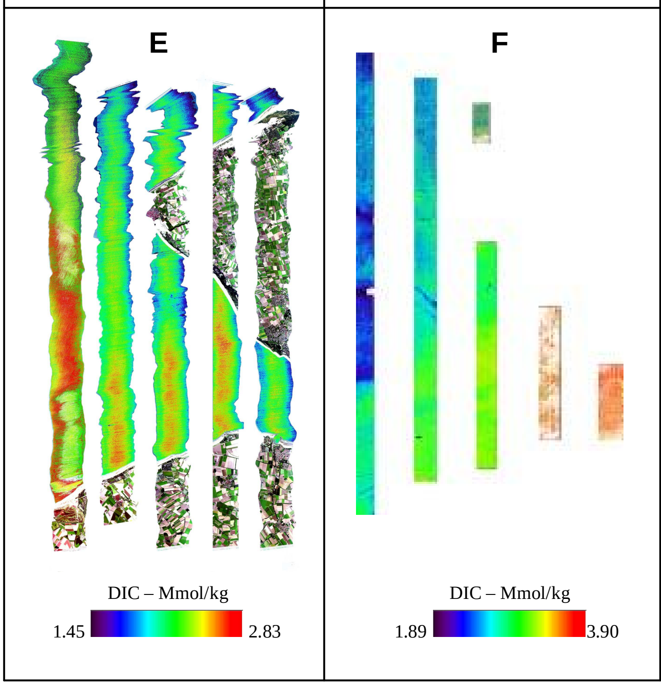
	parameter	Correlation (%)	$parameter = A + B \cdot \left(\frac{b1}{b2}\right) - C\left(\frac{b3}{b2}\right)$
1	Cryptophytes	96.91	b1(0.577); b2(0.566); b3(0.714)
2	Dinoflagellates	96.61	b1(0.555); b2(0.657); b3(0.498)
3	Diatoms (*10+6 ind)	72.70	b1(0.646); b2(0.634); b3(0.657)
4	PCO_2 (ppm)	72.70	b1(0.543); b2(0.476); b3(0.465)
5	DIC (mmol/kg)	71.70	b1(0.589); b2(0.476); b3(0.465)
6	DOC (µmol)	76.60	b1(0.577); b2(0.566); b3(0.510)
7	CDOM (absorb 380 nm)	70.22	b1(0.588); b2(0.521); b3(0.510)
8	Chl a	48.21	b1(0.634); b2(0.487); b3(0.498)
9	Chl c_2	72.62	b1(0.703); b2(0.691); b3(0.818)
10	Chl b	44.20	b1(0.498); b2(0.611); b3(0.498)

Table 1 – Multiple regression results.

Table 1 presents the multiple regression results (highest correlation coefficient and related spectral bands). As we can see, high correlation was obtained with this method for the phytoplankton species Cryptophytes and Dinoflagellates. However, according to in situ measures, these species were not important in term of biomass. No significant correlation was obtained for Chl a and Chl b.

Figure 2 presents the synoptic map of several biogeochemical parameters. Figure 2A is a true colour presentation of the CASI corrected images. Very shallow sandbanks can be observed in the western flight lines (very bright zone resulting from saturation of the sensor). Sun reflection at water surface might contribute to this kind of artefact. In the south of the western line, a discharge plume can clearly be observed from the shoreline (reddish zone). Figure 2B show a high concentration of CDOM (yellow substance, gilvin) at the mouth of the estuary (eastern line) and along the shores.For some part of the estuary, the distribution of dissolved organic carbon (DOC) derived by the reverse algorithm seems to reproduce bathymetry patterns. Therefore, the validity of this particular regression is put in doubt until further investigation.
As could be expected, distribution obtained for PCO_2 (Figure 2E) and DIC (Figure 2F) are very similar. A clear across track geometrical artefact can be observed on these maps (higher values at the centre of flight lines compared to the edges). In order to remove this low frequency signal, a 2nd degree polynomial filtering was applied on the average across track signal of each spectral band, for each flight line. The distribution of DIC resulting from this treatment is illustrated in figure 2E, were





highest dissolved inorganic carbon concentrations are observed at the mouth of the estuary. Downstream along the southern coast, DIC concentration reduces, whereas lowest values are associated with open seawaters and the incoming anti-cyclonic current from the north.

CONCLUSIONS

Multiple regression technique proved very convenient method for first statistical exploration of large hyperspectral databases. Some results obtained with this algorithm are encouraging (i.e. CDOM, DIC). In case of limited number of ground truth stations, attention should be paid to the general distribution range and pattern established in order to avoid inconsistent correlation.
CASI data recorded over water seems affected by “sun glim” systematic artefacts as revealed clearly by some parameter distribution (i.e. DIC) Bathymetry effects (i.e. DOC).
Some zones should be masked in first flight line, consequently to intense direct sun reflection on water surface, and to the presence of very shallow sandbanks (probably responsible for extreme values in the range). First attempt to remove signal artefact was realised with cross-track filtering, further work is still required.

Figure 2: A – True color CASI corrected image; B-E results before cross track filtering: B – Color Dissolved Organic Matter (CDOM), C -Dissolved Organic Carbon (DOC), D – Pressure CO_2 (PCO_2), E - Dissolved Inorganic Carbon (DIC); F – DIC after cross track filtering.

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