HIGH SPATIAL RESOLUTION REMOTE SENSING OF THE PLYMOUTH COASTAL WATERS

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ABSTRACT

CHRIS-PROBA has the potential to provide high spatial resolution satellite ocean colour imagery that is applicable to the mapping of estuarine and coastal waters. This paper follows on from the CHRIS-PROBA 2004 workshop paper [1], which demonstrated CHRIS-PROBA's potential, and shows the results of applying an atmospheric correction to the Version 4 data for an example 06 March 2003 image acquired using mode 2 (water bandset). The results continue to be encouraging and demonstrate that CHRIS-PROBA is progressing towards being suitably well characterised and calibrated for applications in coastal waters.

Further research will be carried out in 2005, including the continuing goal of acquiring contemporaneous airborne data and in-situ measurements.

1. INTRODUCTION

Most spaceborne ocean colour sensors are of use for studying the coastal environment, but are of a limited value for estuaries because their spatial resolution (several hundred metres to 1 km) is too coarse for many European sites. However, Compact High Resolution Imaging Spectrometer (CHRIS)-PROBA offers observing capabilities appropriate to estuarine monitoring. It has a spatial resolution of 25 metres and provides multi-look angle imagery, which can be used to improve the atmospheric correction (AC). For the United Kingdom (UK) Rame Head water test site, the CHRIS-PROBA imagery is complemented by Compact Airborne Spectrographic Imager (CASI) imagery flown by the Natural Environment Research Council (NERC) Airborne Remote Sensing Facility that has a spatial resolution of less than 10 metres (see Fig 1a). The site includes the turbid Case II (dominated by suspended particulate matter, SPM, and coloured dissolved organic material, CDOM) waters of the Tamar estuary, less turbid waters of Plymouth Sound and summer Case I waters (dominated by phytoplankton) of the English Channel.

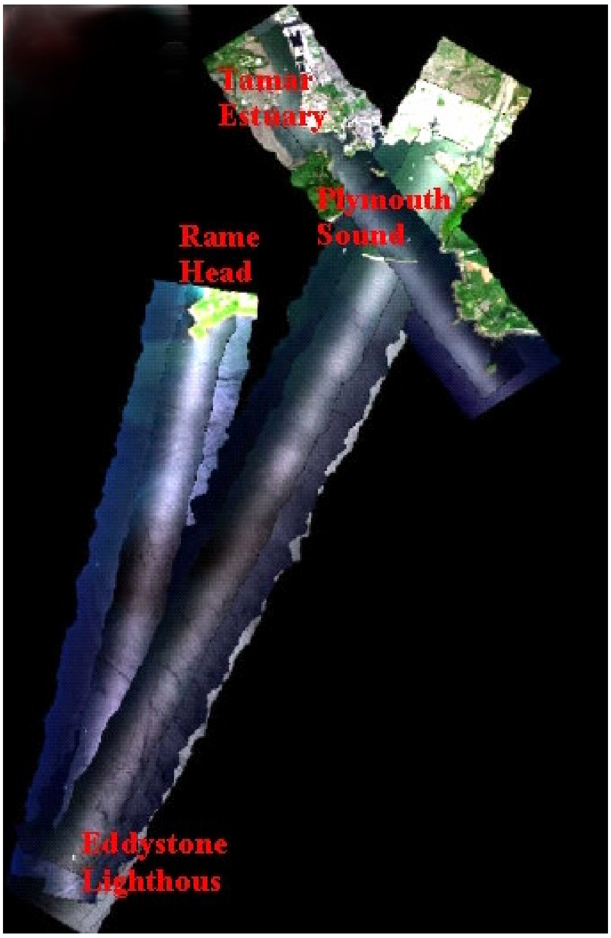

Fig. 1. Uncorrected multi-height CASI imagery from the 13th June 2003 mosaiced (smaller swath width imagery on top) to show the mouth of the Tamar estuary, Plymouth Sound and coastal waters out to the Eddystone lighthouse.

Table 1 shows the CHRIS-PROBA 2004 imagery acquisitions and attempts at contemporaneous airborne (CASI) and in-situ campaigns. Truly contemporaneous data collection was not achieved due to the juggling of logistics and cloud conditions, but the datasets provide valuable information with the future prospect of qualitative comparisons. There was enhanced sampling in 2004, as compared to 2003, with measurements of chlorophyll-a in addition to SPM and CDOM.

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Table 1. Fieldwork conducted in 2004.

CHRIS imagery	Coverage	CASI imagery / cloud conditions.	In-situ Data
07 Feb 2004	Lower estuary, Sound and R Head.	Significant cloud, but less over the lower estuary and Sound.	No data collected.
01 Mar 2004	R Head	Good.	09 Mar: Plymouth Sound.
26 Mar 2004	R Head? Cloud obscured	Dominated by cloud and so poor.	16 Mar: Tamar transect.
19 Aug 2004	Lower estuary, Sound and R Head.	Some scattered cloud, but shows interesting features.	No data collected.
09 Sept 2004	No CHRIS-PROBA.	CASI of estuary.	No data collected.
08 Oct 2004	No CHRIS-PROBA.	CASI of estuary.	08 Oct: Tamar transect.
19 Nov 2004	Lower estuary, Sound and R Head.	Dominated by cloud, but the lower estuary and Sound may be retrievable.	No data collected.

2. METHODOLOGY

A CASI atmospheric correction was developed [2] using the knowledge gained from the development and implementation of the SeaWiFS [3] and MERIS [4] processing code. This was modified to take the CHRIS-PROBA imagery so that a preliminary validation of its ocean colour capabilities could be performed. The details of the CHRIS-PROBA implementation are given in the 2004 workshop paper [1], which for this paper was updated using the:

- new radiometric calibration implemented by SIRA

- sensor zenith and azimuth angles with the field-of-view (FOV) for across image variations

- wavelengths and bandwidths from the HDF file and therefore adjusting atmospheric parameters for each image

- quality map from the HDF file and removing saturated/PPU reset data.

3. RESULTS

The AC was carried out on an example CHRIS-PROBA image from the 06 March 2003 with a combination of wavebands (11, 6 and 3) used to produce colour composites (Table 2). The uncorrected top of atmosphere reflectance for the Version 3.0 3309 (nominally nadir) image is shown in Fig. 2a with the Version 4.0 3309 (nominally nadir), 330B (nominally -36 degrees off nadir) and 330A (nominally +36 degrees off nadir) images in Fig. 2b to Fig. 2d. The two numbers correspond to the actual zenith and azimuth angles produced in the updated SIRA processing and available in the Version 4 HDF file. It is interesting to note that both the 3309 and 330B images actually have zenith angles of 20 to 25 degrees off nadir. The third image (330A, Fig. 2d) has a much greater zenith angle of around 47 degrees off nadir, and the uncorrected reflectance appears to be significantly brighter in comparison to the other two look angles.

Table 2. CHRIS mode 2 water bands with the CASI bands indicated using an asterisk.

Waveband	Application	Waveband	Application
(1) 405.6 - 415.2*	MERIS	(10) 645.7 – 655.8*	MOS
(2) 438.0 - 446.8*	CIMEL / MERIS	(11) 666.3 - 677.2*	CIMEL / MERIS
(3) 485.6 - 494.8*	MERIS	(12) 677.2 - 682.8	MERIS / FLH
(4) 504.5 - 514.8*	MERIS	(13) 682.8 - 688.5	MERIS / FLH
(5) 525.6 - 534.2*	MODIS	(14) 700.2 - 712.4*	MERIS
(6) 556.1 - 566.3*	MERIS	(15) 751.9 - 758.9	Red Tide Index (RTI)
(7) 566.3 - 577.1*	SPM / Bathymetry	(16) 773.4 - 788.4*	MERIS
(8) 584.6 - 596.4*	SPM / Bathymetry	(17) 863.1 - 881.3*	CIMEL / MERIS
(9) 617.5 - 626.6*	MERIS	(18) 1002.7 - 1035.5	CIMEL

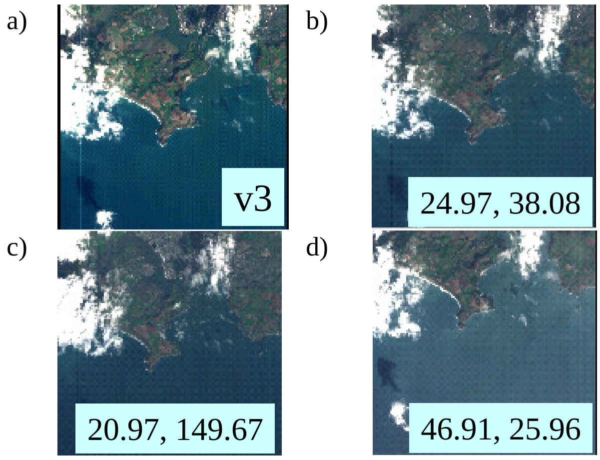

Fig. 2. CHRIS-PROBA uncorrected top of atmosphere reflectance imagery for the 06 March 2003. The coloured images represent composites of wavebands 11, 6 and 3 as red, green and blue. a) and b) are the Version 3 and 4 3309 image with c) and d) being the Version 4 330B and 330A images.

Before the AC is applied a non-water mask is used to remove pixels that should not be processed, with the results of applying the non-water mask shown in Fig. 3. The mask was generally successful for both the 3309 and 330B images (Fig. 3b and 3c), but only the cloud shadow has been recognised as water in the 330A image (Fig. 3d). This indicates that there has been a shift in the spectral shape of bands 16 and 17, which are used in the mask [2].

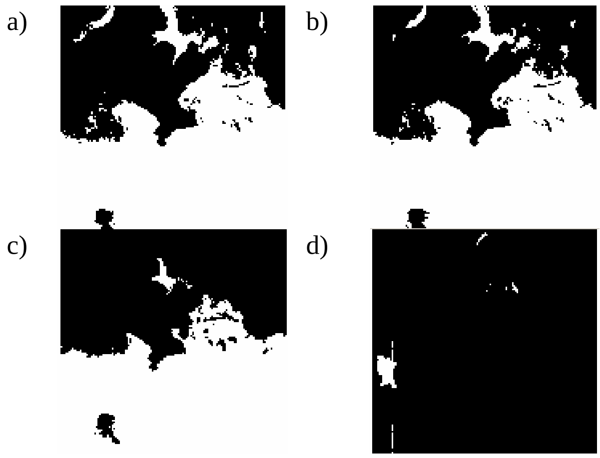

Fig. 3. CHRIS-PROBA non-water mask for the 06 March 2003. a) and b) are the Version 3 and 4 3309 image with c) and d) being the Version 4 330B and 330A images.

To analyse the spectral reason why image 330A wasn't non-water masked correctly (Fig. 3d) an offshore point was selected (Fig. 4a) with the top of atmosphere uncorrected reflectance and calculated aerosol reflectance being compared for each angle and for the satellite ocean colour Sea-viewing Wide Field-of-view Sensor (SeaWiFS) [5] that was acquired on the same day (Fig. 4b). Generally the CHRIS-PROBA and SeaWiFS values match-up well, but a deviation can be seen in the 330A image where the top of atmosphere reflectance has a smoother spectral shape and no reduction in reflectance from band 16 to 17 is seen. Also, the calculated aerosol reflectance increases from the blue to red part of the electromagnetic spectrum. Overall, from the viewing geometry and change in spectral shape, it can be concluded that image 330A is contaminated by sunglint that needs to be removed prior to the non-water mask and atmospheric correction.

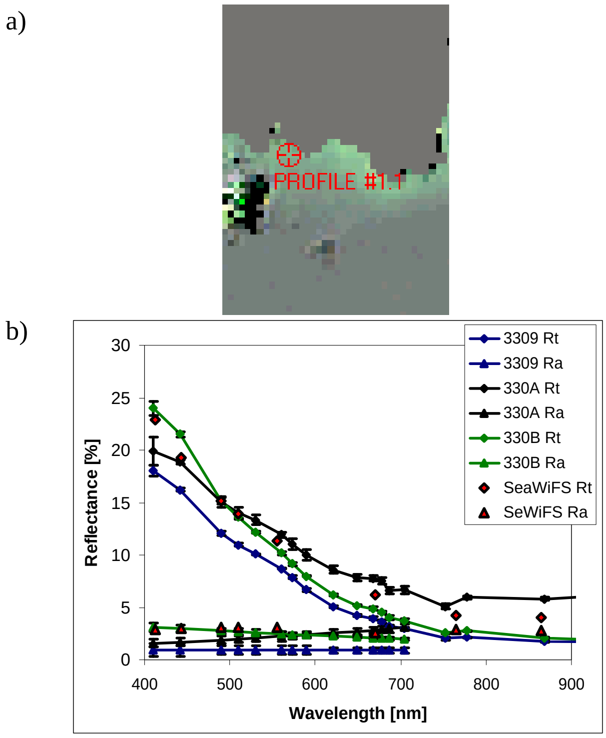

Fig. 4. An offshore point (a) was compared for the 6th March 2003 CHRIS-PROBA and SeaWiFS top of atmosphere uncorrected reflectance and calculated aerosol reflectance (b).

Fig. 5 shows the different stages of the AC process being applied to a pixel from the example image; it was located off Rame Head and so in low SPM concentration waters. In the Version 3 processing (Fig. 5a) the first two wavelengths had very high reflectance values, which was recognised as a problem with the radiometric calibration. This has been corrected in Version 4 (Fig. 5b) and the overall spectrum shows a much more realistic shape and magnitude. This is demonstrated by a close match-up to SeaWiFS when it is taken into account that the two sensors have very different pixel sizes (25 m and 1 km respectively) and further work is still required for CHRIS-PROBA.

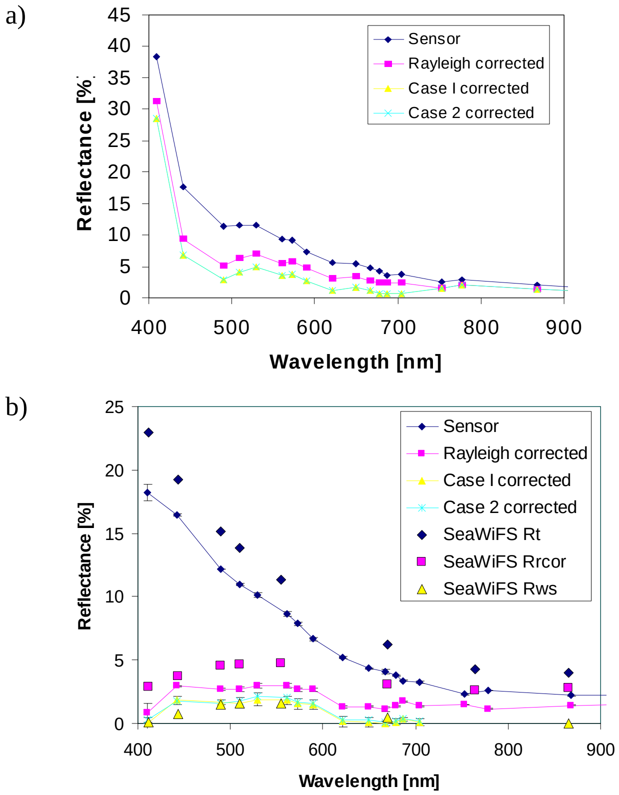

Fig. 4. Spectral curves extracted from a 6th March 2003 CHRIS-PROBA pixel off Rame Head for the a) Version 3 and b) Version 4 processing with SeaWiFS extracted data.

4. CONCLUSION AND DISCUSSION

The AC shows promising results, but needs further refinement and there needs to be a process for the remove of sunglint contamination if all the viewing geometries are to be used. To validate the atmospheric correction we also need to compare the derived above water reflectance to concurrent *in-situ* reflectance measurements. Therefore, in 2005 the fieldwork will be repeated in an attempt to get contemporaneous in-situ, CASI and CHRIS-PROBA data. However, comparisons with coarser resolution ocean colour sensors in the offshore waters have proved to be a useful source of comparison data when in-situ observations are not available.

During 2005 imagery will also be acquired using the Disaster Monitoring Constellation (DMC), which has several small satellites with a spatial resolution of 32 m and 3 Landsat equivalent spectral bands (green, red and near infra-red) [6]. The lack of wavebands (two near infra-red bands are required for a conventional ocean colour atmospheric correction) and sensitivity will require a modification of the processing, but previous research has shown the usefulness of this data for monitoring SPM [7]. The additional data will progress research towards an operational monitoring system where there is sufficient remote sensing data for it to be assimilated into a sediment transport model.

5. REFERENCES

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6. ACKNOWLEDGEMENTS

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