CTCD CHRIS-PROBA ACTIVITIES

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ABSTRACT/RESUME

This paper describes the work currently being undertaken by researchers within the NERC Centre for Terrestrial Carbon Dynamics (CTCD) with CHRIS-Proba data. The paper focuses on information extraction on crop and forest cover types over our two test sites (Barton Bendish and Harwood Forest).

1. A SPARSE INTERPOLATED LUT INVERSION

The aim of the work over crop canopies has been to develop a robust rapid method for the inversion of canopy reflectance models using multi-angular hyperspectral data from CHRIS. A method has been developed whereby, given suitably atmospherically-corrected data, a sparse look-up table (LUT) is generated for the particular wavelengths and viewing/illumination angles of an acquisition using a canopy reflectance model such as that due to Nilson and Kuusk (1989) to populate the LUT. Along with each spectral reflectance sample, the partial derivatives are also strored, giving (m+1)xNxlxn LUT samples for l wavelengths, n view angles, m parameters and N LUT grid points. It is found that the LUT can be as small as between N=500 and N=1000 without greatly altering the accuracy of the resultant inversion. The method works by selecting the LUT grid point with the 'best match' to each observation and a first-order extrapolation from this point using the partial derivatives at this point to find the global minimum of the error function.

Whilst this inversion scheme works very well and is quite rapid, a much greater speed of processing can be achieved by compressing the LUT and performing the inversion in this 'compressed' space. Compression is achieved by calculating a set of Empirical Orthogonal Functions (EOFs) on the canopy reflectance LUT, each EOF being defined over the lxn samples of the data. It is found that the signal can be very well represented with only a small number k of EOFs (typically around 3 for greater than 99% of the variance in the LUT), which means that the RMSE needs only be calculated at Nxk LUT points, rather than Nxlxm as previously required. The interpolation can be performed in the compressed space or in the original data space.

An additional feature of this compressed LUT representation is that the EOFs essentially provide an expectation of the directional spectral reflectance, which means that the first few EOFs, representing the vast majority of expected variation, can be used to solve for atmospheric effects.

The current status of this work is that the three scenes collected over Barton Bendish in 2003 (27/03/03; 13/06/03; 16/10/03) are currently undergoing reprocessing with updated calibration information.

2. PHOTOCHEMICAL REFLECTANCE INDEX (PRI)

Our main UK forest site is Harwood Forest in Northumbria, a CarboEurope flux tower site contuously measuring Carbon and other fluxes over the chronosequence of Sitka Spruce stands. The stands are very dense, with a very low proportion of light at the understorey. The main focus for work being undertaken at the site is the calculation of PRI at high spatial resolution. PRI is a simple normalised difference index that shows a strong relationship with light use efficiency (LUE) at the leaf level due to changes in Xanthophyll concentrations under light saturation:

$$PRI=(R570- R531) /(R570+R531) \qquad (1)$$

LUE provides information on the efficiency with which intercepted light is used by the leaves and can be directly used to calculate Gross Primary Productivity in the canopy. There is potential to calculate this index, thence LUE from moderate resolution spaceborne sensors such as MODIS and MERIS, but a good deal of further work is required to test the robustness of the signal and its scaling properties. To this end, we are investigating the link between PRI calculated from CHRIS-Proba data and fluxes measured at the Harwood Forest test site. For 2005, we also have a PRI sensor mounted on a tower to provide top of canopy PRI measurements. We have also undertaken helicopter over-flights at various times during 2003 and 2004 to obtain top of canopy spectral reflectance, along with various Daedalus ATM and CASI over-flights.

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We were somewhat unfortunate in 2004 in that only a single relatively clear image of the site was obtained. This is shown in figure 1 as a multiple view angle composite. The various stands of Sitka Spruce can be observed in the image, although much of the variation in the chronosequence is obscured by cloud.

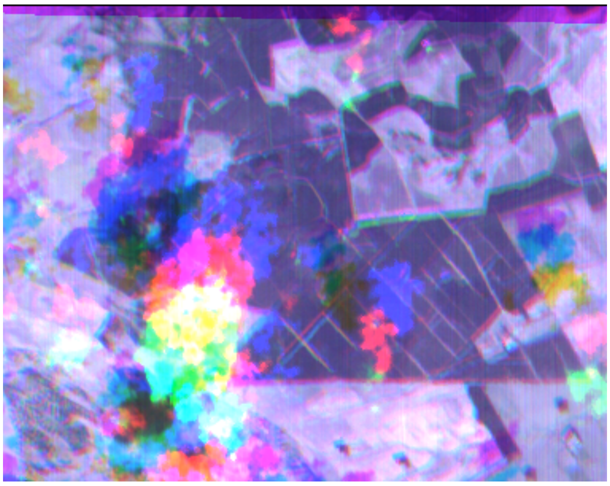

Fig. 1. Multiple View Angle Composite image of Harwood Forest, with nominal 0° +36° and -36° views on red green and blue respectively.

An additional Flux tower site, at Griffin forest in Southern Scotland, has been proposed for CHRIS-Proba acquisitions this year.

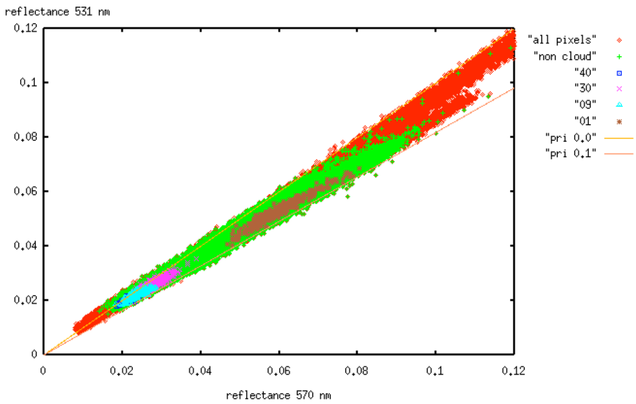

Fig. 2. Scatterplot of reflectance at 531nm against that at 570nm for near nadir CHRIS-Proba view.

Figure 2 presents a scatterplot of reflectance at 531nm against that at 570 nm. We can clearly see that the PRI signal we are attempting to detect is very small in magnitude, representing only around 2% of the variance in the signal over these two wavebands. Figure 3 shows the mean reflectance over a 30-year-old Sitka stand as a function of viewing angle.

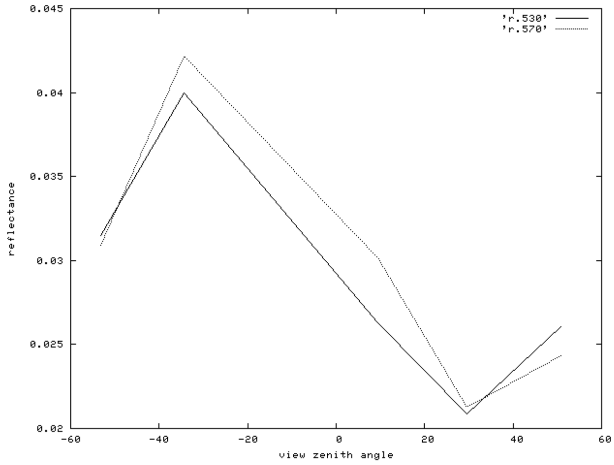

Fig. 3. Reflectance at 531nm and 570nm over a 30-year-old stand.

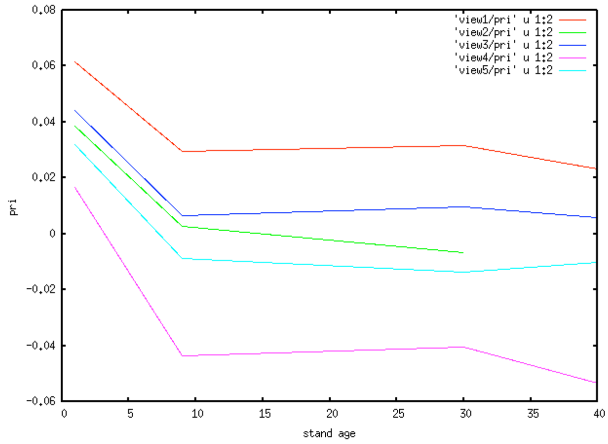

Fig. 4. PRI for the various view angles of CHRIS-Proba for various stand ages (1, 9, 30 and 40 years).

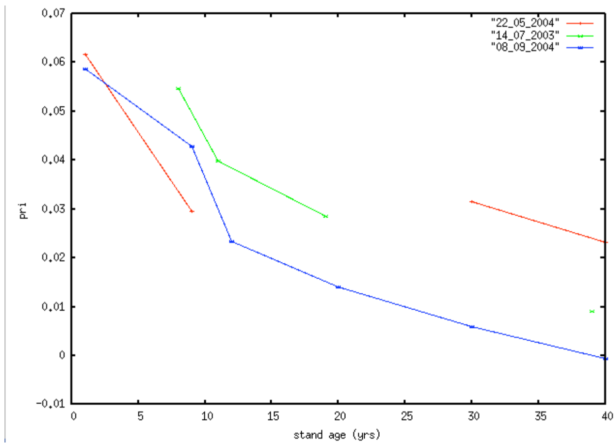

Fig. 5. PRI for various stand ages from CHRIS-Proba and helicopter data.

As predicted in modelling studies (Bartion and North, 2001) we can see that the PRI signal will show a strong angular variation (figure 4). The same basic behaviour in PRI is seen for all stands: a peak near nadir and decreasing PRI with decreasing view angle. Figure 5 shows PRI for various stand ages from the CHRIS-Proba data (22/05/2004) and from two helicopter flights. The same trend (decreasing PRI with increasing stand age) is seen for all datasets, although there is significant variation between the different dates.

This is most likely due to compound effects of variations in solar zenith angle as well as the 'expected' variations in PRI over the year. We cannot decouple these effects from the data collected so far. The acquisition plan for 2005 involves further sets of overflights and flux tower measurements (the latter to relate the PRI/LUE to GPP) as well as monthly CHRIS-Proba acquisitions over the year.

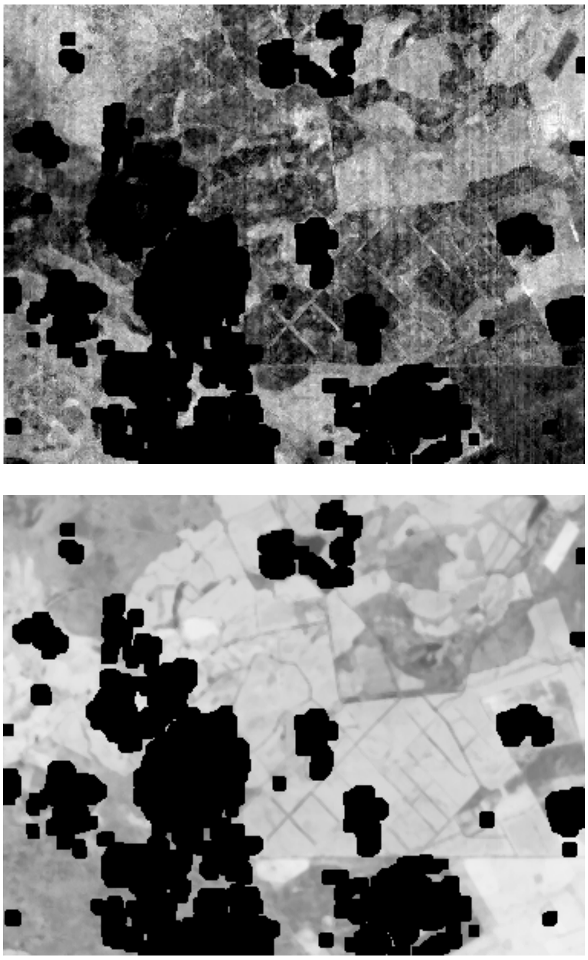
Fig. 6. Upper Image: Nadir PRI from CHRIS-Proba (scaled 0.0-0.1); Lower Image: Nadir NDVI from CHRIS-Proba (scaled 0.0-1.0).

Figure 6 shows an image of PRI calculated from the near-nadir CHRIS-Proba image, along with the equivalent NDVI image. NDVI is closely related to fAPAR, which when multiplied by IPAR and LUR gives GPP, so the product of these two images essentially gives the remote sensing products that can be used to calculate GPP.

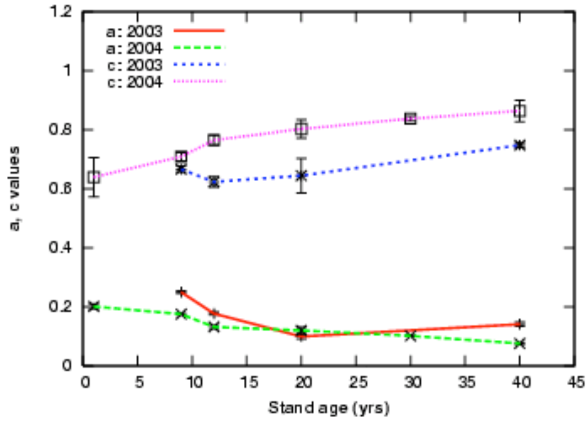

Fig. 7. Geometric parameters from helicopter data

3. FUTURE DIRECTIONS

There are a large number of issues when attempting to estimate GPP from satellite data using the methods described above. These include directional variations in both PRI and NDVI due to the influence of understorey reflectance and other factors such as the PRI/LUE being different for sunlit and shaded leaves. Whilst calculation of NDVI and PRI might form a rapid and simple way to estimate GPP from satellite data, it is likely to lack robustness. A more fruitful way to proceed, that we are also exploring, is to calculate fAPAR from a knowledge of the canopy biophysical quantities through the inversion of a canopy reflectance model such as described in section 1. The subtleties of the LUE signal can then be calculated either from PRI at the leaf-level reflectance obtained by such a model inversion or from the inversion of xanthophyll concentration more directly from the leaf signal.

Whilst full inversion of a canopy reflectance model is rather complex, we note that some progress might be made in deriving the leaf scattering function from the canopy reflectance by assuming scattering to be described by a simple Neumann series for a canopy bounded by a dark surface (as is the case here):

$$\rho = a\omega/(1-c\omega) \qquad (2)$$

where ρ is the canopy reflectance and ω the leaf single scattering albedo. Such a model has been proposed by Knyazikhin *et al.* (1998) and Smolander and Stenberg

(2005) who note that the 'c' term here is equivalent to the "eigenvalue of radiative transfer equation", which can also be thought of as a 'recollision probability'. The term 'a' is simply the geometric probability of interception in the canopy multiplied by the scattering phase function. Given equation 2, we can determine the values of the geometric parameters a and c if the leaf single scattering albedo is known. We have achieved this for the data from the helicopter over-flights (fig. 7) but not yet processed from the CHRIS-Proba data.

4. CONCLUSION

The estimation of both PRI and canopy biophysical parameters looks to be very feasible from the high information content data obtained by CHRIS-Proba. We have developed a method of performing canopy reflectance model inversion using a sparse compressed interpolated LUT which shows much promise. We have also demonstrated that although the PRI signal is very small, a convincing map of this parameter can be estimated from CHRIS-Proba. We have noted that PRI seems to vary considerably with view angle. Work during 2005 will concentrate on examining the PRI signal monthly over the Harwood and Griffin Forest test sites and developing an understanding of this signal in comparison to flux tower data, tower measurements of PRI, and helicopter and fixed wing over-flights.

ACKNOWLEDGEMENTS

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