Answers - GLaSS Training material, Lesson #8

Part 1 The effects of absorption

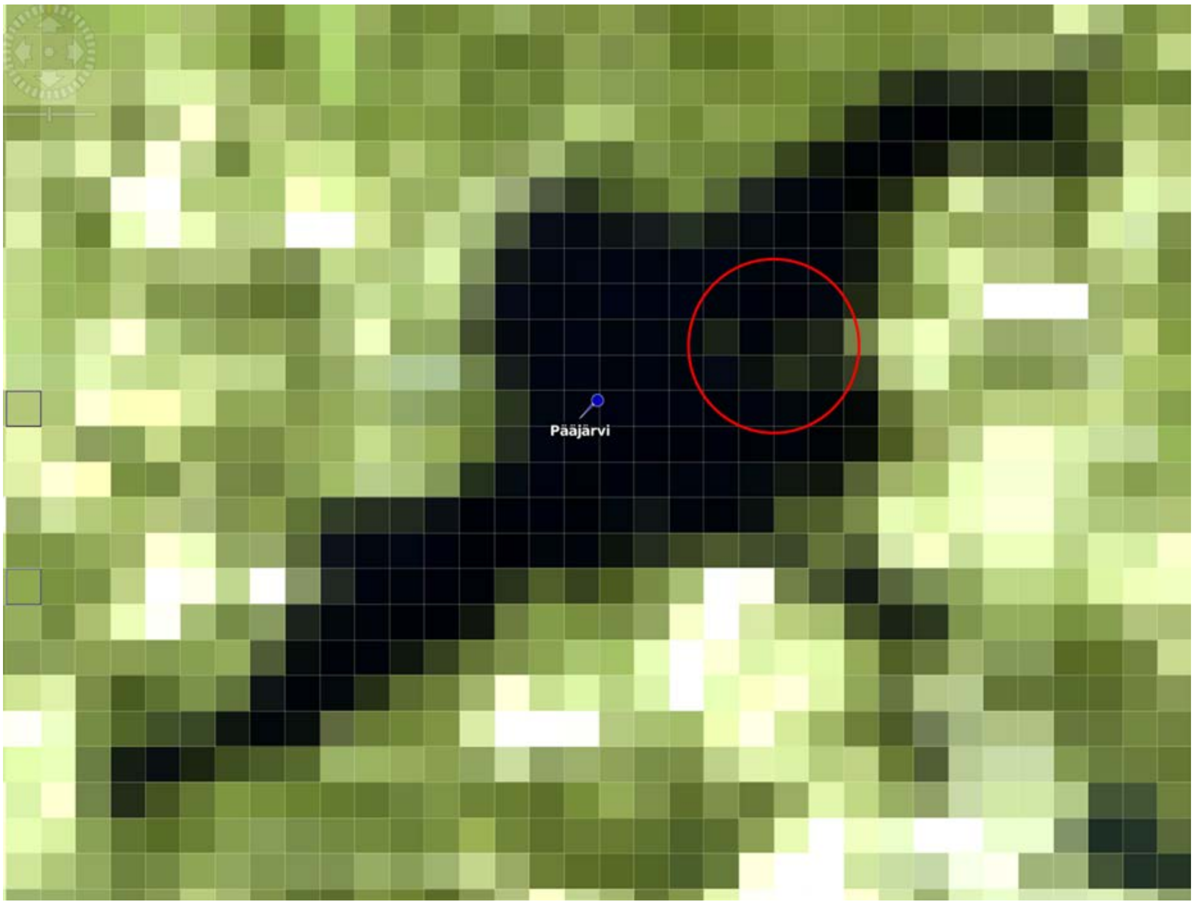
In the folder Answer data you will find the file Results_1_Lakes_processor.xls, which shows you the results.

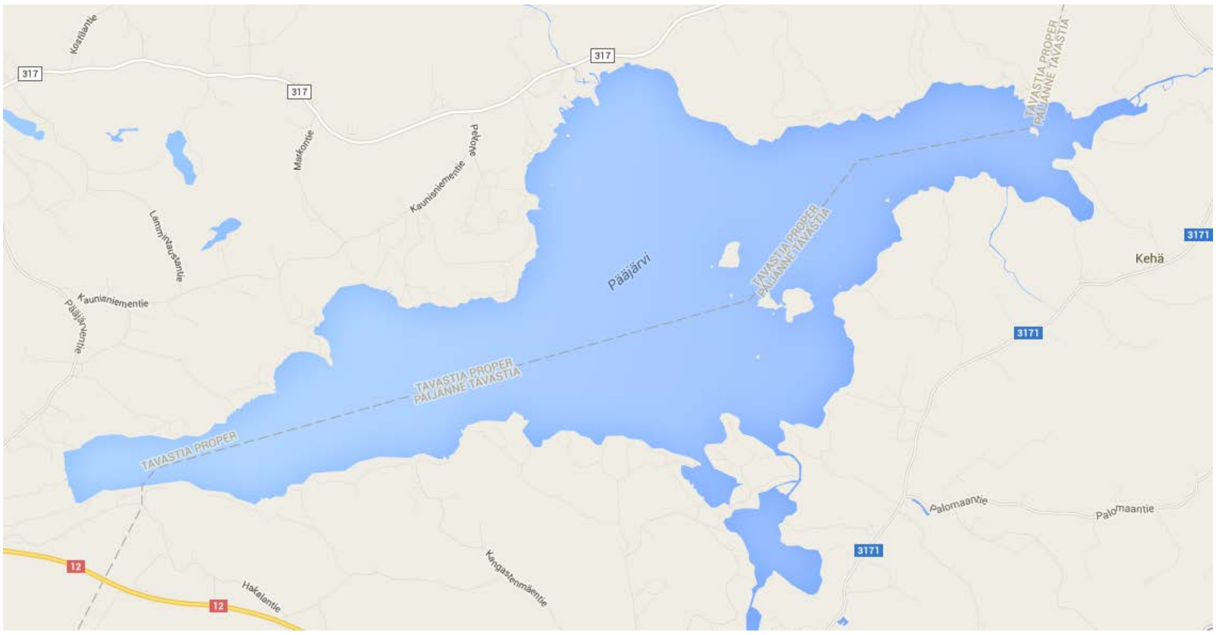
The Lakes processor works reasonably for lakes Pyhäjärvi and Vesijärvi and fails for Päijänne and Pääjärvi.

CDOM basically absorbs the light entering the water, leading to a lower signal. TSM also scatters the light, so that a higher TSM concentration leads to a higher signal. TSM can therefore partly compensate for CDOM absorption. Therefore, Pääjärvi (with the highest CDOM content) and Päijänne (with intermediate CDOM but even lower TSM) reflect the least amount of light. This explains why the atmospheric correction fails for these lakes.

Part 2 Mixed pixels and the adjacency effect

There are mixed pixels on the shores of Lake Pääjärvi. This shoreline contains of smaller bays and inlets, all leading to mixed pixels. However, there are also some unexpected brighter spots in the middle. If we compare the RGB image with Google maps we learn that there are some small islands (< 100 m diameter) which completely fall into the MERIS pixels (300 m). These pixels contain a mixture of land and water, and might therefore not be recognized as water by processors. However, any obtained water quality parameter from these pixels will also not make sense.





In the folder Answer data you will find the file Results_2_ICOL.xls, which shows you the results after ICOL processing.

After applying the adjacency correction processor ICOL, the reflectance results improved. For lakes Pyhäjärvi and Vesijärvi the intensity got better, for Päijänne and Pääjärvi also the spectral shape improved. However, the results for Päijänne and Pääjärvi are still off, especially in the blue wavelengths.

In the folder Answer data you will find the file Results_2_Percentages.xls, which shows you the results of the last step in Part 2.

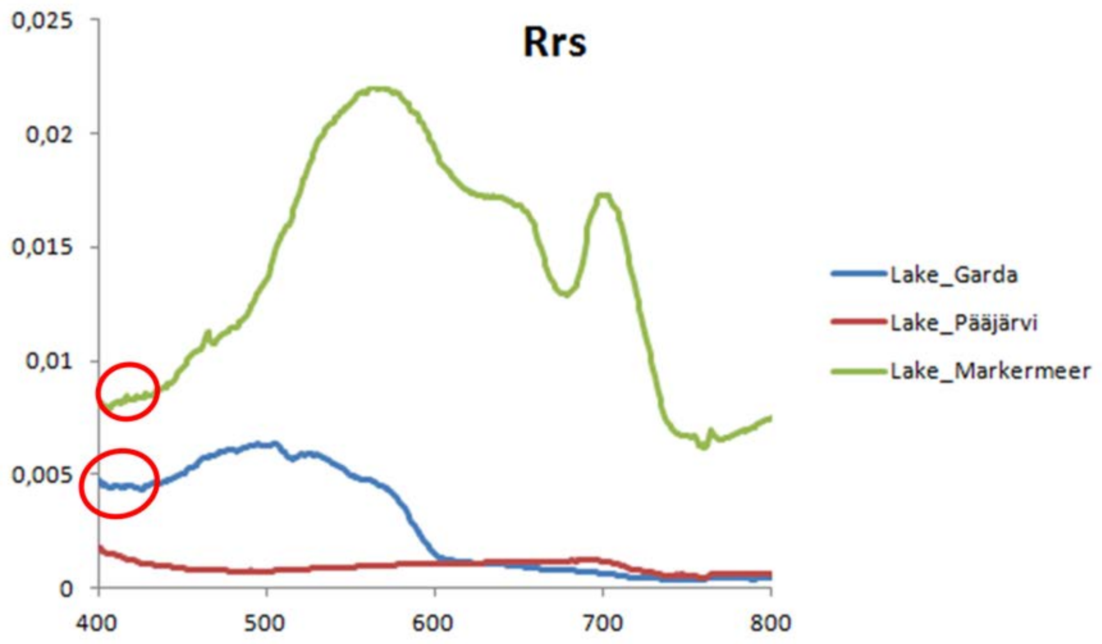
The surface reflectance of these lakes consists of a maximum of 9-10 % of the TOA radiance. For Lake Päijänne (2%) and Lake Pääjärvi ~ 4%) is even lower. This means that the correction for downwelling sunlight and the atmospheric correction have to take away minimum 90% of the signal that was received by the satellite (for Päijänne even minimum 98%). It does make sense that small inaccuracies in this correction process will cause a relatively large effect on the results.

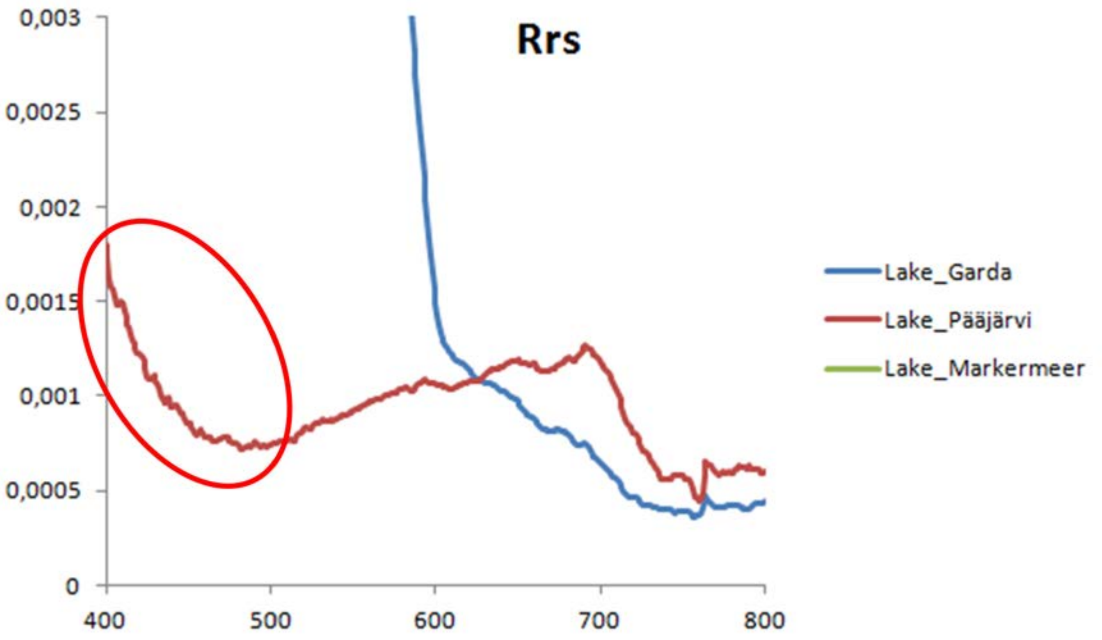
Part 3 Sensitivity

The Ed and Ld spectra of these three measurements are comparable. Only in the case of Lake Garda there was apparently a little less sun. This is just co-incidence. The main difference comes from the water leaving signal (Lu). The shape and especially the intensity is very different. This is reflected in Rrs. The reflectance of Lake Markermeer is the highest. Is also has a high reflectance in the green, red and near-infrared parts of the spectrum (>600 nm). The reflectance of Lake Garda is much lower than that of Lake Markermeer, but especially in the blue/green (<600) much higher than that of Lake Pääjärvi.

The spectral shape of Rrs for Lake Pääjärvi is not as expected. Because of the high CDOM concentration, it would be expected that the reflectance at wavelengths < 500 nm would be very small (caused by a high absorption of blue light by CDOM).

One possible reason for the increase in the blue Rrs for Lake Pääjärvi, is imperfect (too small) sky radiance correction, which has a relatively large effect on the low-reflecting lake. It can also be an effect of sensitivity of the instrument. The reflectance of Lake Pääjärvi is so low, that the signal is in the range of the black current ("noise"). The same effect can also slightly be seen in the Rrs spectra of the other two lakes (see images below, the sensitivity effect is shown in the red circles).





Factors that influence the accuracy of the measurement are:

1. The instrument itself, the radiometer that was used. We will not go into details here.
2. The calibration should be done properly. Especially for low-light situations, it must be checked that the accuracy of the calibration is not lower than the measurement requires.
3. Field of view. If the instrument measures Ld with a larger opening angle, the measured surface is larger and more light will be captured. A higher signal leads to a better signal-to-noise ratio. The measurements in the example spreadsheet were measured with a 3-degree opening angle. This makes it easy to point at an exact location to measure, but it reduces the amount of light compared larger opening angles.
4. Downwelling light. On a clear sunny day, the signal is higher and therefore automatically the signal-to-noise ratio will be better, even if the instrument and measured property (lake) are the same.

The amount of light coming from Finnish lakes can be quite low when the concentration of CDOM is high. This can be a limiting factor for the use of EO. All measurements include noise and when the signal is weak the noise can cause large measurement errors. The measurement accuracy of products derived from satellite images depends on the quality of the atmospheric correction and the bio-optical inversion (e.g. the validity of specific inherent optical properties, SIOPs).

However, as for hand-held instruments, the accuracy also depends on instrument sensitivity and the amount of light that is received by the sensor. Let' s go through the list that was just presented for a hand-held sensor:

1. The instrument itself, the radiometer that was used. As for in situ instruments, satellite instruments have different accuracies
2. The calibration. When working with water, the instrument sensitivity and calibration of sensors that were developed for land (which is much brighter than water) might in some cases be the limiting factor.
3. Instead of an opening angle like for hand-held instruments, satellite instruments with a high spatial resolution generally have a lower sensitivity. Comparable to an in situ instrument, if the area that is measured is higher, the amount of received light per pixel is higher and the noise is relatively smaller. The other way around: when the pixel size is smaller, the signal-to-noise ratio will be lower. This effect is clearly shown in the table below, where the noise equivalent for the same MERIS sensor, however, using two settings (300 m pixel size or 1000 m pixel size) are compared.
4. Downwelling light. On a clear sunny day, the signal is higher and therefore automatically the signal-to-noise ratio will be better, even if the instrument and measured property (lake) are the same. It is important to check the sun elevation during overpass: time of the day and latitude in combination with season can have a large influence on the quality of the data of a satellite sensor.

Noise equivalent radiances (NER) for MERIS Reduced Resolution (RR) and Full Resolution (FR) data (Doerffer 2008).

Band wavelength (nm)	RR NER (mW m^{-2} sr^{-1} nm^{-1})	FR NER (mW m^{-2} sr^{-1} nm^{-1})
412	0.060562365	0.24224946
443	0.051189618	0.20475847
490	0.04815864	0.19263456
510	0.03950104	0.15800416
560	0.031496063	0.12598425
620	0.027456647	0.10982659
665	0.02247191	0.08988764
681	0.029644269	0.11857708
708	0.019448947	0.07779579
753	0.056311881	0.22524752
761	0.248670213	0.99468085
778	0.009817672	0.03927069
865	0.010434783	0.04173913
900	0.051980198	0.20792079