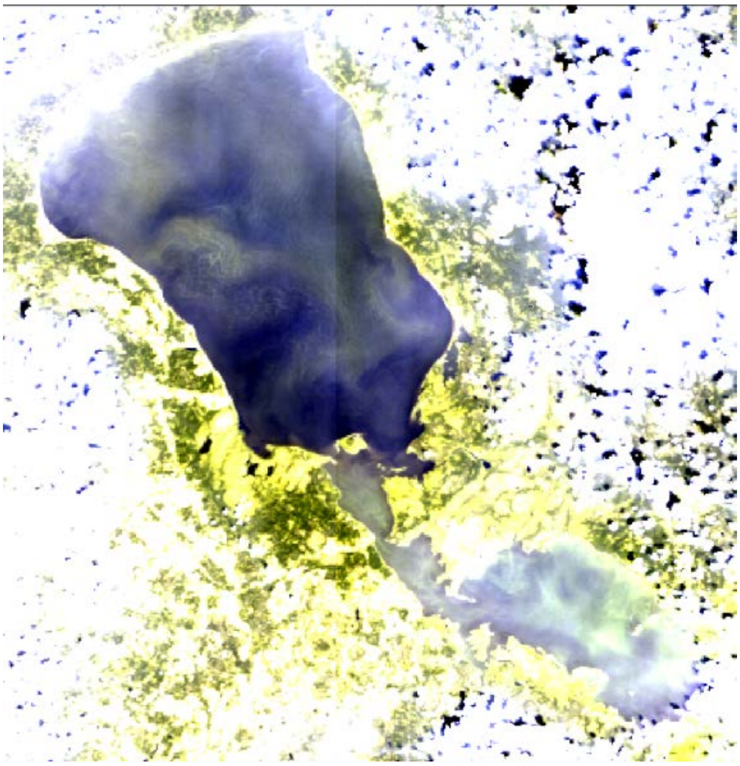
Answers - GLaSS Training material, Lesson #3

Part 1, Basic visual analysis of spatial variability

The exported DIMAP file can be found in the folder Answer_data.

MERIS L1 true colour images after adjusting the colour scale can be found below. There is a slight haze of clouds over the north/eastern part of the lake



Part 1 Extra analysis

In the image of 8 July 2011, there are more clouds. Next to the clouds, there are cloud shadows. It is easy to ‘flag’ (remove) the cloud pixels by an algorithm that recognises very bright pixels. However, cloud shadows are difficult to remove because they can are dark while water itself is also dark.

Part 2 Atmospheric correction

The units of radiance reflectance (upwelling radiance from the water divided by downwelling irradiance from the sky, also referred to as remote sensing reflectance, Rrs), is $^{-sr}$. This means per sterradian.

The maximum reflectance of the in situ data is 0.16 to 0.25 $^{-sr}$ (depending on the station). This maximum is found at 550. The colour of 500 nm is green. Apparently the colour of the water was dominated by green, due to algae blooms.

The maximum reflectance of the L1 MERIS data above water is about 70 mW/m2*sr*nm. This maximum occurs at 412 nm. The colour of 412 nm is blue. This makes sense, as the dominant colour atmospheric reflection is blue.

After running the atmospheric correction algorithm (CoastColour), the land and cloud pixels are removed. These do not contain information on the water quality.

The maximum reflectance of the atmospherically corrected data is ~0.012-0.035 $^{-sr}$. This maximum is found at 550. Indeed, after atmospheric correction the reflectances are similar to those that were obtained in situ.

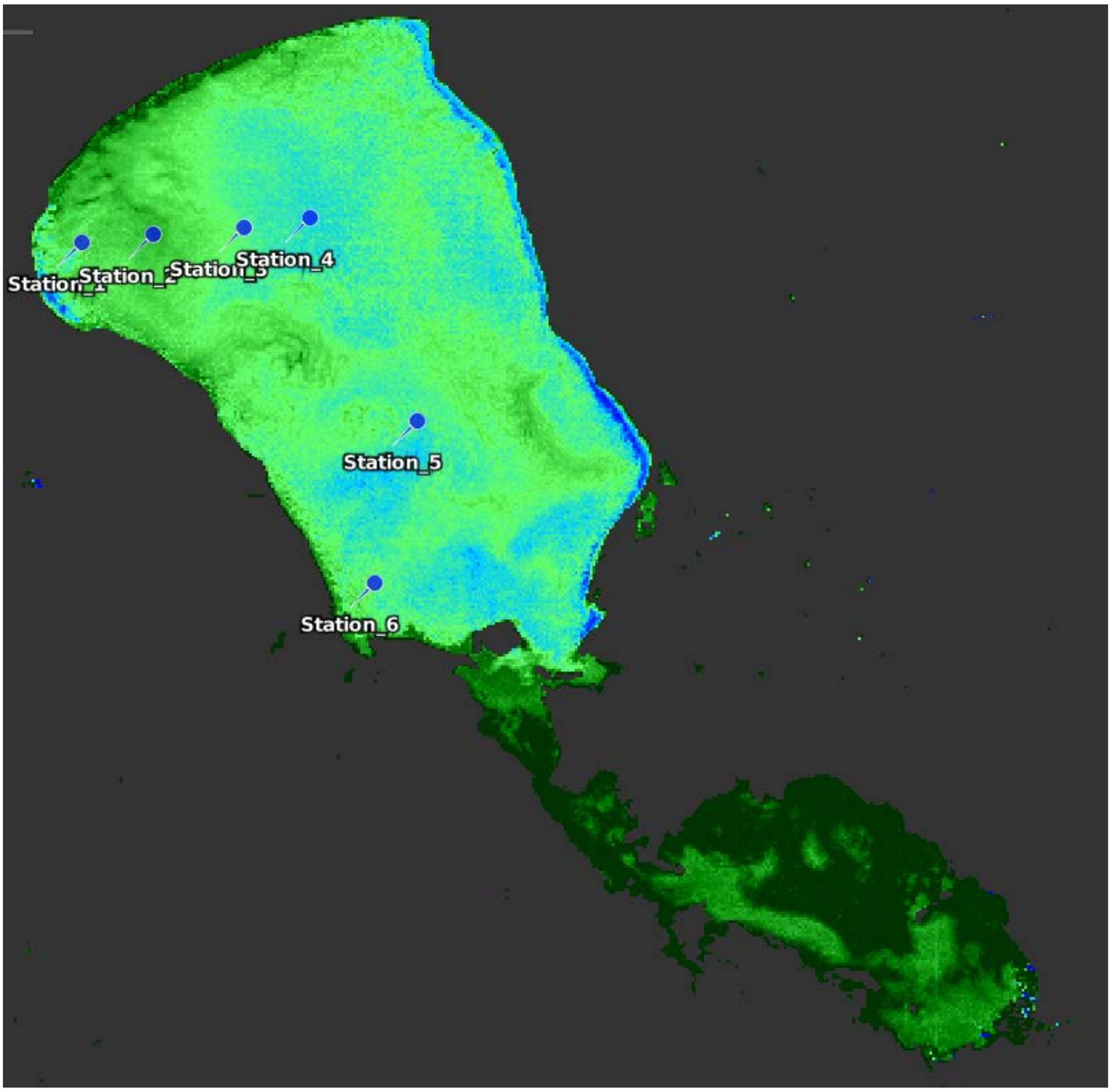
Part 2 Extra analysis

The folder Answers contains the L2 (atmospherically corrected) image, the exported file and a spreadsheet with the reflectances measured in situ and obtained from CoastColour atmospheric correction processing.

The atmospheric correction worked reasonably. It is not perfect. In GLaSS deliverable 3.2 many different atmospheric correction methods were compared. CoastColour performed relatively very good for Lake Peipsi. However, from the comparison it becomes clear that atmospheric correction for inland waters is still not solved.

Part 3 In water component retrieval

The folder Answers contains the fully processed image with the colour scale and the pins of the stations. A screenshot is shown here:



The spatial patterns can still be found. In lake Pikva the chlorophyll concentration is higher than in the northern part (Peipsi SS).

The coastal zone on the north/eastern shore shows low concentrations. This is not logic, as often concentrations of chlorophyll are higher along the shorelines, due to nutrient input via runoff and water (shallower) water. Also wind can move algae to the shore. Also, if we go back to the L1 RGB image, this does not provide a reason for the lower concentrations along this shoreline. The most reasonable explanation is the adjacency effect. Because of scattering of photons in the atmosphere, high reflective items (e.g. land) can 'pollute' the pixels of lower reflecting items (e.g. water). Therefore, the atmospheric correction is not sufficient and based on those also the concentration calculations can go wrong. It is advised to always be very careful with using the concentrations retrieved from satellite imagery very close to the shore.

The folder Answers contains the spreadsheet Chlorophyll_concentrations_validation.xls, with the in situ and the MERIS retrieved chlorophyll. It shows that for four of the six stations the results are quite good. For two stations the concentrations measured in situ are higher than from the satellite. For stations 3 and 4 the results do not agree very well. If you zoom in to these stations and check the concentrations as calculated for the pixel in which the station is located and the pixels bordering the 'station pixel' (the 3*3 pixel window) you will notice that there is a high variability. For example, for station 4, for the pixel where the station is, the concentration is ~20 µg/l, while for the station diagonally to the north-west, the concentration is 27.

It is important to realise that we compare laboratory data that was sampled at one specific spot from a ship, with a concentration retrieved from a 300*300 m satellite image, averaged over that complete surface. For the satellite, the Chl data represents the concentrations over the depth trough which the light penetrates into the water (the optical depth). For the in situ sample, also an integrated sample over a depth profile was taken.

CY blooms tend to have extreme spatial variability (Kutser, 2005; Wynne et al., 2010; Lunetta et al., 2015), thus validation with in situ data from a single point in comparison with 300-m pixel might lead to erroneous results.

There might have even been a time lag of a couple of hours between the two measurements.

Therefore, based on this small dataset, we cannot conclude if the variability that we found between the in situ and the satellite data is due to an error (e.g. in the applied atmospheric correction and/or algorithm for chlorophyll retrieval), or just to spatial variability.

Part 3 Extra analysis

The processed results can be found in the ' Part 3 extra' folder, also the plots with the in situ measurements are available.

The patterns in Chl as calculated via the Gons' method and the FLH method are similar. However, with Gons there are concentrations, while for the FLH method there are 'index' numbers.

In GLaSS Deliverable 5.2 (2015), the FLH algorithms was used to generate long term time series for Lake Peipsi, but also for other lakes in Estonia, Finland, Italy and Germany.

References

- GLaSS Deliverable 5.2, 2015. Global Lakes Sentinel Services, D5.2: Shallow lakes with high eutrophication and potentially toxic algae. TO, SYKE, WI, CNR, BC, VU/VUmc. Available via: www.glass-project.eu/downloads
- Kutser, T., D. C. Pierson, K. Y. Kallio, A. Reinart & S. Sobek. 2005. Mapping Lake CDOM by satellite remote sensing. *Remote Sensing of Environment* 94: 535 - 540.
- Lunetta, R. S., B. A. Schaeffer, R. P. Stumpf, D. Keith, S. A. Jacobs & M. S. Murphy. 2015. Evaluation of cyanobacteria cell count detection derived from MERIS imagery across the eastern USA. *Remote Sensing of Environment*, *157*: *24-34.*
- Wynne, T. T., R. P. Stumpf, M. C. Tomlinson & J. Dybleb .2010. Characterizing a cyanobacterial bloom in western Lake Erie using satellite imagery and meteorological data. *Limnol. Oceanogr.* 55: 2025–2036