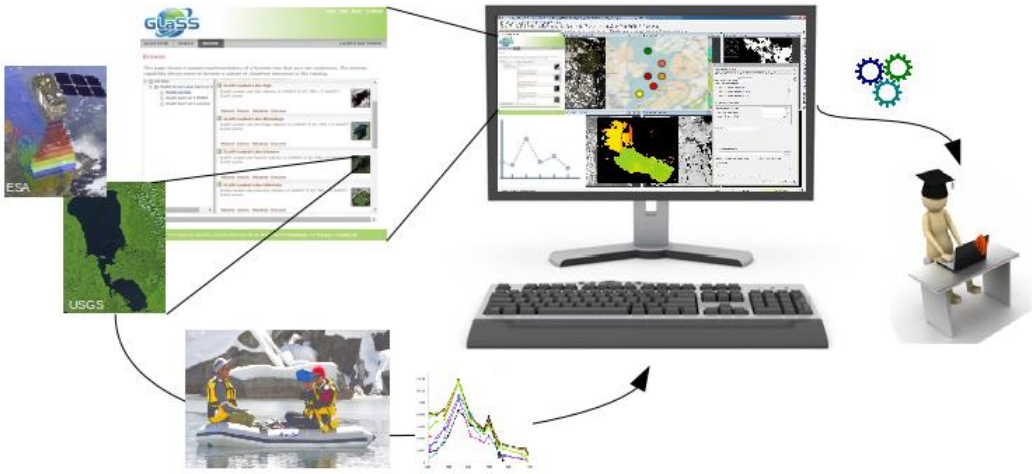
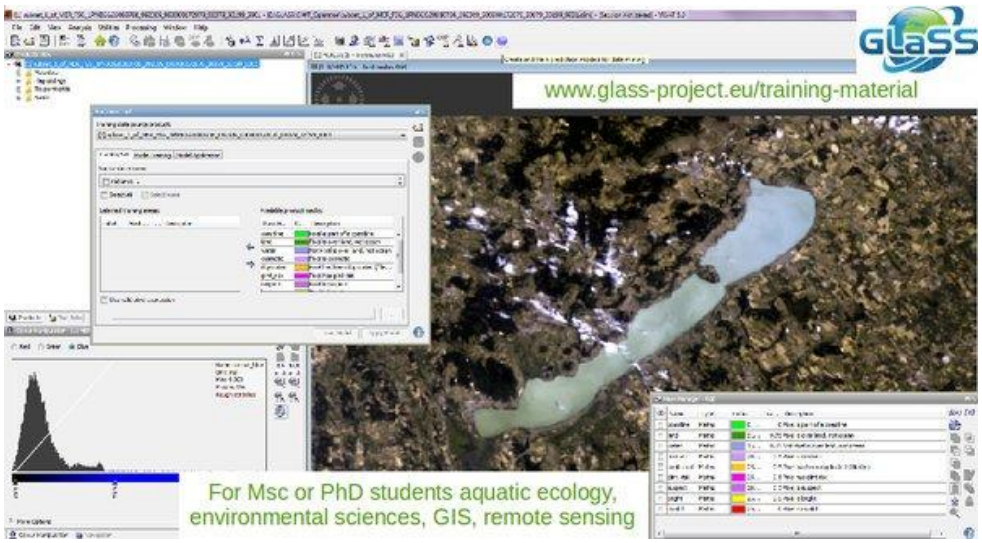
The GLaSS project

Monitoring of water quality of inland waters is important in every days life, for drinking water, transport, recreation, agriculture (including drinking water for cattle and or irrigation) and for ecology. Water samples provide detailed information, but are limited in time and space. Earth Observation (EO) can provide a great spatial overview, which is very useful for ecologists and water mangers. The high spatial resolution of Sentinel-2 and the high overpass frequency of Sentinel-3, combined with their high locational accuracy, will provide unprecedented monitoring capabilities for inland waters.
The EU collaborative project Global Lakes Sentinel Services (GLaSS, www.glass-project.eu) developed a a core system to ingest and process Sentinel data of the lakes of interest. Algorithm tests have been performed and many tools were developed to work with the data. Global lakes use cases demonstrate what can be done with the new Sentinel and other EO data with regard to monitoring, trend analysis and classification such as for the Water Framework Directive.



Training materials

The GLaSS training material (10 lesson) builds on the global lakes use cases of GLaSS. It allows students (((Bsc), Msc, PhD) and professionals in fields as aquatic ecology, environmental technology, remote sensing and GIS to learn about the possibilities of optical remote sensing of water quality, by using the Sentinel-2 and Sentinel-3 satellites and Landsat 8.



Lesson #1: Data handling

- **Research question:** What are the specifications of Sentinel 2, 3 and other high resolution sensors regarding temporal, spatial, spectral characteristics and access mechanisms and what tools are available for analysing?
- **Authors:** Karin Schenk, Philip Klinger, Ana Ruescas, Kerstin Stelzer (EOMAP and Brockmann Consult)
- **Lesson summary:** The Sentinel 2 and 3 data handling session introduces the spatial, temporal, spectral and format specifications of the european multispectral high resolution sensors Sentinel 2 and 3 of the Copernicus programme as well as for Landsat operated by USGS. The lesson provides information about access mechanisms and image importing software solutions, all demonstrated with exercises on selected test data sets in order to learn how to select and handle satellite data for water quality monitoring purposes.
- **Overall aim:** Learn what are the specifications of Sentinel 2, 3 and Landsat, how to access them and which tools are available in order to select suitable satellite images for water quality monitoring purposes
- **Learning objectives:**
    - Knowing about the specifications of Sentinel 2, 3 and Landsat in terms of spatial, temporal and spectral resolution and data formats
    - Being able to access the data, open the data to prepare further analysing activities
- **Download the package**:
    - Exercise (Pdf)
    - Data package (Zip archive)
    - Answers (Pdf)

Lesson #2: Tools for GLaSS data analysis

- **Lesson scope:** Tools for statistical analysis of EO data: optical water types, spatial and temporal analysis by lake, image classification approaches, and semi-automatic pixel selection.
- **Authors:** Ana Ruescas (Brockmann Consult)
- **Lesson summary:** The goal of the lesson is to familiarize EO data users with the tools developed for the GLaSS project that are available in BEAM/SNAP. These tools are focused on image classification and statistical analysis of data. The training material is prepared for the understanding of the optical water tool (GLaSS Deliverable 3.3, 2014), and the image classification method (Magic Wand and Prediction tool, (GLaSS Deliverable 3.6, 2014) included currently in BEAM 5 and that will be transfer into SNAP in the short term.
- **Overall aim:** Familiarize EO data users with some of the tools available in BEAM/SNAP for data classification and statistical analysis on lakes.
- **Learning objectives:**
    - Learn to work with the OWT classification tool: what it can do and its limitations, based on exercises on Lake Balaton
    - Learn to work with thee prediction tool: what it can do and its limitations, based on exercises on Lake Balaton
- **Download the package**:
    - Exercise (Pdf)
    - Data package (Zip archive)
    - This lesson does not contain answers

Lesson #3: Eutrophic lakes

- **Research question:** Research question: What is the spatial distribution of water quality parameters over Lake Peipsi?
- **Authors:** Evelin Kangro, Kersti Kangro, Elar Asuküll, Annelies Hommersom (Tartu Observatory and Water Insight)
- **Lesson summary:** Problems with eutrophication and algal blooms around the world have generated the need for cost-effective ways of monitoring the ecological status of water bodies and its changes. Earth Observation methods have proved to give far better coverage both in spatial and temporal scale for evaluation of in-water constituents in the water bodies. In this lesson we will learn how to analyse the spatial variability in algal concentrations in Lake Peipsi, Estonia, using MERIS satellite data. This includes some basic handling of the image, atmospheric correction, application of a concentration-retrieval algorithm and finally validation of the results with in situ measurements.
- **Overall aim:** Learn how to use satellite data to retrieve chlorophyll concentrations, as a proxy for eutrophication.
- **Learning objectives:**
    - Open an optical satellite image and perform some visual analysis on spatial variability
    - Apply an atmospheric correction method
    - Validate the results with in situ data (spectral+concentrations)
- **Download the package**:
    - Exercise (Pdf)
    - Data package (Zip archive)
    - Answers (Pdf)

Lesson #4: Assessing trophic status tendency from 10-years observation from MERIS

- **Research question:** Is Lake Tanganyika subject to eutrophication?
- **Authors:** Kathrin Poser, Steef Peters, Ilaria Cazzaniga, Claudia Giardino, Mariano Bresciani (Water Insight, CNR)
- **Lesson summary:** Deep clear lakes are characterised by large volume of good quality waters thus providing a wide range of ecosystem services (e.g. biodiversity, climate change mitigation, fishery, drinking water, tourism and recreation). Although these lakes are less vulnerable to eutrophication than small shallow lakes, a continuous input of nutrients has led to increasing eutrophication in many of them. Conversely, improved practices in water management (e.g. fertilisation policy) might lead to trophic status decreasing in other lakes. This lesson covers how we can use satellite data to assess the trend of trophic level in Lake Tanganyika, the third largest lake in the world by volume, one of the richest freshwater ecosystems supplying fish in the diet of the one million people living around the lake.
- **Overall aim:** To analyse trends in the trophic level evolution in Lake Tanganyika. Teaching students on how to assess the trophic status tendency in a big deep clear lake based on processing of long term time series of MERIS data.
- **Learning objectives:**
    - Visualisation of MERIS-derived products
    - Spatial analysis
    - Definition of region of interests (ROI) on image data
    - Application of BEAM tools on time series of Chl products for long-time series analysis
    - Use of Kendall test to statistically assess if there is a monotonic upward or downward

trend in Chl data

- **Download the package**:
  - Exercise (Pdf)
  - Data package (Zip archive)
  - Answers (Pdf)

Lesson #5: Phytoplankton phenology in deep clear lakes

- **Research question:** Does the offset of phytoplankton blooms in Lake Constance change?
- **Authors:** Karin Schenk, Thomas Heege, Ilaria Cazzaniga, Claudia Giardino, Mariano Bresciani (EOMAP and CNR)
- **Lesson summary:** Phytoplankton constitutes the base of the trophic web in freshwater environments and their biomass is coupled to all upper trophic levels. Phytoplankton biomass is sensitive to environmental change, with shifts in the seasonality of blooms, known as phenology, in response to temperature, nutrients and other environmental changes. Since phytoplankton phenology in terms of onset, peak and end or variable growth rates for has to be captured at the high frequency, satellite remote sensing is a suitable technology. This lesson covers how satellite data allow phytoplankton phenology investigations for Lake Constance, a large deep clear lake between Germany, Switzerland and Austria.
- **Overall aim:** The aim of this lesson is to investigate the phenology response of Lake Constance in terms of onset of phytoplankton bloom and spatial distribution.
- **Learning objectives:**
  - Visualisation of MERIS-derived products
  - Investigation of phytoplankton abundance (in terms of Chl concentration) during the year in different sub-basins
  - Definition of region of interests (ROI) on image data based on different tools
  - Finding the timing of phytoplankton growth onset basic on statistics applied to time-series Chl data
- **Download the package**:
  - Exercise (Pdf)
  - Data package (Zip archive)
  - Answers (Pdf)

Lesson #6: Shallow turbid lakes

- **Research question:** What is the effect of wind on resuspension in Lake Markermeer?
- **Authors:** Annelies Hommersom, Marieke Eleveld (Water Insight and VU-university)
- **Lesson summary:** In shallow lakes with a soft bottom, wind waves can easily reach the bottom and resuspend and mix this bottom material up into the water column. The high turbidity can make these lakes less attractive for recreation, and for fish and birds that need to see their prey. The high turbidity also reduces the underwater light intensity and therefore the amount of submerged vegetation and locations of shelter for macrofauna and prey fish. In this lesson we Learn how to use satellite data to visualise the effect of wind waves and other disturbances (such as dredging) in shallow turbid lakes. First, medium resolution MERIS imagery will be used to study the effect of wind on resuspension. Next, we will have a look at the added value of high resolution (Formosat, Landsat 8 and Sentinel 2) data.
- **Overall aim:** Learn how to use satellite data to visualise the effect of wind waves and other

disturbances in shallow turbid lakes. Find out about the added value of high resolution data.

- **Learning objectives:**
  - Use the NIR to analyse the effect of wind on resuspension and other disturbances in lake Markermeer
  - Find out about the added value of high resolution data
- **Download the package**:
  - Exercise (Pdf)
  - Data package (Zip archive)
  - Answers (Pdf)

Lesson #7: Assessing colour of lakes influenced by glacier dynamics in the Mount Everest Region

- **Research question:** Which Himalayan lake could cause glacial outburst floods?
- **Authors:** Erica Matta, Ilaria Cazzaniga, Claudia Giardino, Mariano Bresciani (CNR)
- **Lesson summary:** Glacial lakes, whatever their origin and position with respect to glaciers, are strongly influenced by glacier dynamics that are extremely sensitive to climate change. Increasing melting rates induced by this phenomenon can have various effects among which the increase of both number and size of glacial lakes. Melting water from glaciers is in fact a main factor determining lake volume, but it also contributes to the loading of glacial sediments in the fronting lakes, whose waters are grey and very turbid. This lesson covers how we can use satellite data to classify the multiple lakes in the Sagarmatha National Park (SNP), an exceptional area with dramatic mountains, glaciers, lakes and deep valleys, dominated by Mount Everest, the highest peak in the world (8,848 m). The classification aims to recognize lakes colour and turbidity in terms of water reflectance brightness by focusing on finding potentially dangerous lakes with risk of outburst flood.
- **Overall aim:** In this lesson, the main objective is the classification of lakes in Himalayan region through remote sensing products and techniques, on the basis of their own colour, to distinguish among lakes, those fed by glacier.
- **Learning objectives:**
  - Lakes identification and surface extension assessment through remote sensing techniques, classifying image surfaces trough new GLaSS Prediction Tool
  - Assessment of lakes type through remote sensing colour
  - Masks generation for change detection
  - Classifying image surfaces trough new GLaSS Prediction Tool for the evaluation of new grey lakes on glacier tongues
- **Download the package**:
  - Exercise (Pdf)
  - Data package (Zip archive)
  - Answers (Pdf)

Lesson #8: Lakes with a high concentration of humic substances

- **Research question:** What are the limits of remote sensing of water?
- **Authors:** Annelies Hommersom, Sampsa Koponen, Kari Kallio (Water Insight and SYKE)
- **Lesson summary:** Boreal lakes often contain high concentrations of colored dissolved organic matter (CDOM). This leads to strong absorption of light especially in the blue and

green parts of the spectrum, so that the remaining colour is yellow/red/brownish and dark. The low reflectance complicates the use of EO methods, because a low signal easily leads to a low signal-to-noise ratio, while also small errors in for example the atmospheric correction might lead to relatively large changes in the results. In this lesson the student will get an overview of the issues that determine the limits of remote sensing of water, with a focus on the effects of high absorption.

- **Overall aim:** Get an overview of the issues that determine the limits of remote sensing of water
- **Learning objectives:**
    - Find out about the effects of absorption
    - Find out about mixed pixels and adjacency effects
    - Learn about sensitivity
- **Download the package**:
    - Exercise (Pdf)
    - Data package (Zip archive)
    - Answers (Pdf)

Lesson #9: Mine tailing ponds

- **Research question:** Where are potentially harmful mine tailing ponds located?
- **Authors:** Annelies Hommersom, Bram Krommendijk (Water Insight)
- **Lesson summary:** In this lesson we will setup a method to locate potentially hazardous mine tailing ponds. World wide there are hundreds of thousands of these ponds, some of them well maintained, others abandoned and not well documented. Yearly large environmental accidents underline the importance of monitoring. The first step is to locate all ponds. In this lesson we will select suitable satellite data, apply masks and include a lot of logical thinking as a first step in setting up a tool to automatically locate mine tailing ponds in large remote areas based on Earth Observation data.
- **Overall aim:** Where are potentially harmful mine tailing ponds located?
- **Learning objectives:**
    - Selecting the best suitable satellite data and processing level for your purpose
    - Setting up a logic approach
    - Using masks
- **Download the package**:
    - Exercise (Pdf)
    - Data package (Zip archive)
    - Answers (Pdf)

Lesson #10: Assessing ecological status according to the WFD

- **Research question:** How remote sensing could support Water Framework Directive implementation in lakes?
- **Authors:** Ilaria Cazzaniga, Petra Philipson, Claudia Giardino, Mariano Bresciani (CNR and Brockmann Geomatics)
- **Lesson summary:** Lakes are valuable resources and constitute large and relevant water reservoirs whose protection in the European Union is regulated by the Water Framework Directive (WFD). It forces the Member States to monitor systematically all natural and

artificial lakes with surface area larger than 0.5 km2 based on multiple components and parameters. As some of these parameters can be determined by remote sensing, this lesson how we can use satellite data to assess the ecological status of hundred lakes in southern Sweden and how to monitor Lake Vänern status from 2002 to 2012.

- **Overall aim:** To demonstrate how of remote sensing can support the implementation of the WFD. Teaching students on how to assess water quality status according to the limits set by the WFD in Sweden.
- **Learning objectives:**
  - To be informed about the WFD
  - Visualisation of MERIS-derived product
  - Checking differences in southern Sweden lakes based on WFD limit
  - Analysing differences among the Lake Vänern sub-basins depending on WFD regulatio
  - Checking water quality status of Lake Vänern during time
- **Download the package**:
  - Exercise (Pdf)
  - Data package (Zip archive)
  - Answers (Pdf)

For questions, please contact info@glass-project.eu