Marine use of flying drones

How to fly a drone for marine remote sensing purposes in the northern Gulf of Bothnia

Interreg
Aurora

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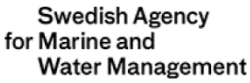
SeaMoreEco



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Förord

The shallow coastal areas of the northern Gulf of Bothnia represent ecologically important areas, distinguished by their rich biodiversity and unique habitats. However, these areas are increasingly vulnerable to the pressures of human activity and the accelerating impacts of climate change. A challenge for management today is the lack of knowledge of occurring species and habitats and practical solutions on how to improve their conservation status.

SeaMoreEco is a Finnish - Swedish initiative that during the years of 2023 – 2025 brought together expertise in marine biology and geology to map coastal habitats as well as develop, test, and demonstrate methods for monitoring, conservation, and restoration in shallow marine environments in the northern Gulf of Bothnia.

This manual is published as one output of the project, with the aim to share the results of the conservation efforts done in the project through monitoring, restoration and population studies of threatened species and habitats in the shallow coastal areas. Through these efforts, the project aims to strengthen the knowledge of marine habitat and their management and foster long-term resilience in the northern Gulf of Bothnia's shallow ecosystems.

The project was financed by Interreg Aurora and co-financed by Regional Council of Lapland and Swedish Agency for Marine and Water Management.

Participating organisations:

County Administrative Board of Norrbotten
County Administrative Board of Västerbotten
Geological Survey of Finland
Geological Survey of Sweden
Centre for Economic Development, Transport and the Environment in North Ostrobothnia
Centre for Economic Development, Transport and the Environment in South Ostrobothnia

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Introduction

This manual outlines the practical steps for planning and executing drone flights in a marine environment and more specifically in the Bothnian bay. Flying a drone over the ocean is different from flying a drone over land. Water reflects light, waves move constantly, and conditions can change quickly

This manual provides simple explanations, practical examples, and helpful tips so you can understand how to use a drone for marine remote sensing. Careful planning is crucial to maximize efficiency during fieldwork and ensure data quality, especially given variable weather and water conditions. The use of drones provides high-resolution data collection capabilities superior to traditional methods in shallow marine areas.

Effective field work is a key part of the image analysis workflow. Days with suitable conditions for drone flights and for producing good quality imagery are limited under the vegetative period. The success of the entire field campaign therefore depends on good preparation and planning.

Planning overview

The planning step is a crucial part of marine remote sensing. Good preparation makes the field work easier and increases the chances of collecting high quality images. Think of planning as “doing the homework” before the real mission. The work can be divided into:

1. **Pre-planning**, which can be done well in advance of the field work. The goal is to get the AOIs, flight areas and other aspect in calm for maximize the field work.
2. **Operational planning**, which must be done close to the field work. And finetuned to the current conditions on the day of the flight. Before your field work and do your flight, you need an overview of the weather and water conditions
3. **Drone settings and flight strategy:** The last part is the drone and the influence of the setting and how to fly that will improve the results.

1. Pre-planning

The pre-planning is about laying the groundwork for an efficient day in the field. It can be done well in advance to the field work. The goal is to strategically plan how the information is going to be gathered, facilitate the operational planning and ensure an efficient field work.

Define and delimit the AOI

Your Area of Interest (AOI) is the region that you want to cover and forms the core area of your drone flights. Before defining it, gather all the relevant pre-existing data. This may include aerial photographs (orthophotos), ground-truth data, analysis results, or earlier inventories. Those are invaluable for understanding the site and delimit the AOI areas. Using historical data will help to avoid unnecessary flight time and plan the field work.

Identify which parts of the flight’s areas are essential to capture, the AOI. These areas should be within comfortable flight range and have priority in the operational planning. When you define and delimit your AOI take in consideration following:

- Ensure that the most relevant area is included, but don’t spend too much time on small details. Draw a simple outline of the area (see Figure 1).
- The AOI area should ideally be smaller than what can be covered with one battery, but in some cases, you want to cover larger areas that require several batteries. This part should be done in a GIS-software, so that the data can be stored in a database and re-used in future field campaigns.

Figure 1. An example of an AOI, orange polygon, drawn to indicate which part of the site must be covered by our flight, red polygon, and resulting drone orthophoto.

Create a naming system for your AOIs

Create a nomenclature for giving names to your AOI. Use a nomenclature that will follow the whole analysis workflow. We recommend the following structure:

- A prefix representing the region or county. An abbreviation is recommended. In our case the acronym “AC” for Västerbotten.
- The name of the seascape or municipality.
- The name of the bay or sea area.
- A suffix that explaining the type, in this case AOI or core area.

The site in Figure 1 lies in the county of Västerbotten, acronym “AC”, in the seascape “Järnäs” and the specific sea areas have the name “Storklubben”, resulting in the name: “AC_Jarnas_Storklubben_AOI”. In the case you work with other countries then you should use a prefix for that.

Know your drone - how much can it fly?

When the AOI are defined, you can start to create a preliminary fly area. Like the drawing of AOI, you can draw rough the shape in which the flight will be done. But before drawing up exact flight areas, you must understand your equipment's limitations.

One is drone performance for the drone you will use. One key question is: How long and how large an area can your specific drone model cover per battery charge? Different models have different capabilities. For examples:

- DJI Phantom 4: ca. 40 ha at 120 m flight height per battery

- DJI Mavic 3 Enterprise: ca 80–90 ha at 120 m flight height per battery

Identify safe take-off and landing sites

Suitable locations: Gravel roads, parking lots, beaches, or other flat, open areas. Choose spots protected from typical wind for the season, for example, behind a cluster of trees (but not too close to the treetops).

Plan carefully to maximize the workday

Efficiency is key, as the available time window for flying is usually limited. Reduce uncertainty by planning thoroughly so that you know exactly what to do when you arrive on site.

- Calculate driving time to your flight areas and walking time to launch sites.
- Minimize unnecessary movement. A drone flies much faster than a person can walk, so avoid walking where the drone can fly.
- Cluster your flight areas when possible. Grouping nearby areas allows you to cover several flights from a single base, reducing time spent driving or walking between locations.

Consider wind exposure and sea breeze

Plan alternative AOIs with different wind exposures. If the wind comes from the north, you can fly in a southerly sheltered area, and vice versa. This way you can fly even under suboptimal conditions, without too many wave-effects.

Sea breeze is a wind that develops during the day over large bodies of water. The earlier hours of the day usually provide calmer conditions that can be used to fly over more exposed areas and on the other hand it's good to plan some more sheltered areas as the day progresses.

Delimit your preliminary flight area

A good starting point is to use sea charts. You can get relatively good boundaries for your flight area based on depth limits (Figure 2). A reasonable operational limit is often around 3 meters, though it can be good to set the limit somewhere between 3 and 6 meters, due to the inaccuracy of sea charts and the possibility to map some deeper parts.

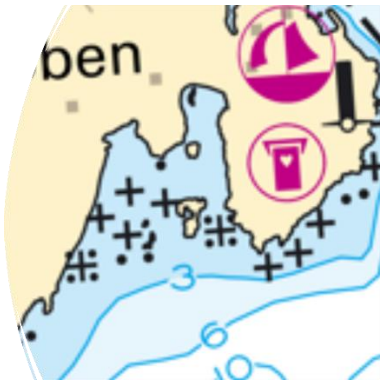


Figure 2. Sea chart showing the bathymetry of a flight area.

Another valuable source of information for delimiting the flights areas are airborne orthophotos, historical and/or time series. Review the orthophotos to get an idea of how much of seafloor was visible under certain conditions. Under good weather and water conditions it's possible to get more visible bottom, this helps you focus on possibly feasible areas (Figure 3).

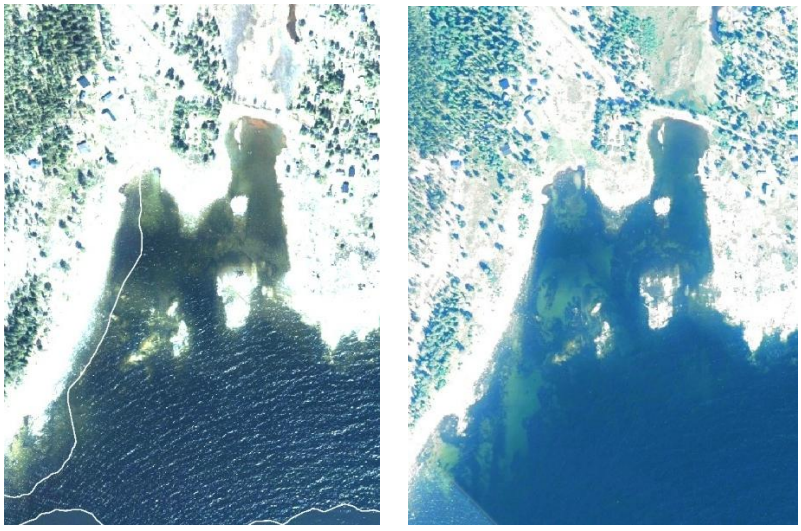


Figure 3. Two orthophotos from different years. Left: reduced bottom visibility and waves. Right: clear visibility of shallow and deep areas.

If previous drone orthophotos exist, can be very useful for identify exactly the AOI and flight area. The example in the figure 4 gives insights to delimit the preliminary flight area.

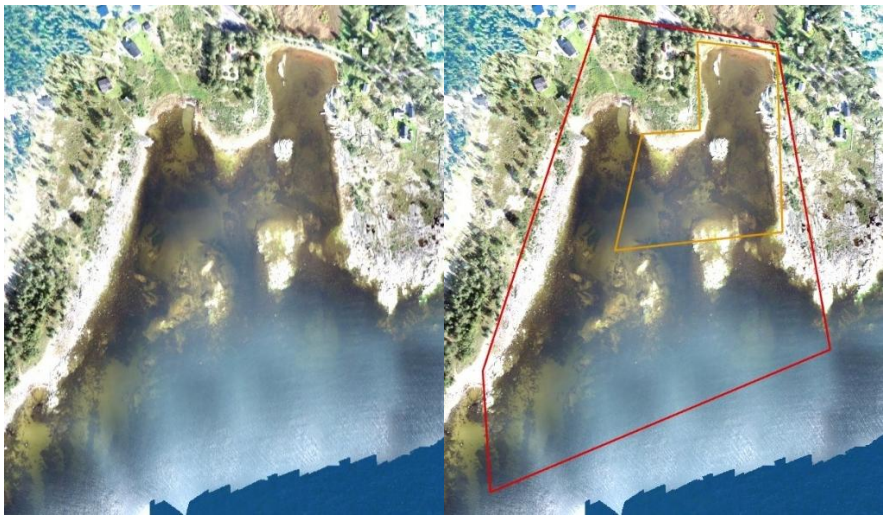


Figure 4. Drone orthophoto and the limits of the AOI or core area, orange, and the flight area, red.

With the information from drone and airborne orthophotos, or from local knowledge, you can find potential take-off and landing zones. Always plan alternatives; depending on the wind conditions you can then choose a more sheltered (blue) or exposed (green) area (Figure 5). In this case the blue area is much closer to the parking spot and the road. The distance to your take-off and landing zones is important. Remember that your drone flies very fast - avoid walking long distances if it is not necessary.

Figure 5. Drone orthophoto showing the AOI (orange), flight area (red), and two potential take-off sites: an exposed site (green) and a sheltered alternative (blue).

Plan your work in clusters and, if possible, try to group areas in a way that they can be completed within one day of good weather conditions. In the example in Figure 6 there are four flights zones. The two biggest require two batteries each, which results in a total of six flights. In this case it is possible

to complete this area within one good day. Alternative, if the weather is favourable only during parts of the day, the work can be divided into two half days.

Figure 6. Flight area clustering for one working day.

In this example, it is possible to choose flight areas depending on the wind conditions. If strong winds create waves and reduce image quality in exposed areas, you can switch to more sheltered alternatives. The eastern areas are protected from westerly winds and may therefore offer better conditions than the western areas. Which zones are suitable will depend on the wind direction on the day of the flights.

2. Operational planning

In the operational planning stage, you review your pre-plans and adapt them to the actual conditions in the field. The most important factors to examine are weather and water conditions, as the quality of the drone orthophotos depends heavily on both. These conditions will guide how you prioritize your fieldwork on any given day. From our experience, careful operational planning is essential to avoid the need to repeat flights due to poor image quality.

Figure 7 shows an area with very good results. The drone orthophoto shows the sea bottom very clearly, even central parts where the depth is around 4 meters. At the time of the flight, water quality was excellent with a Secchi depth of around 6 m compared to the usual 4 m in this area. The weather too, was very calm and sunny, leading to the water surface to almost become invisible. To plan your field campaign efficiently and prioritize where and when to fly, you must examine the weather and water conditions carefully.

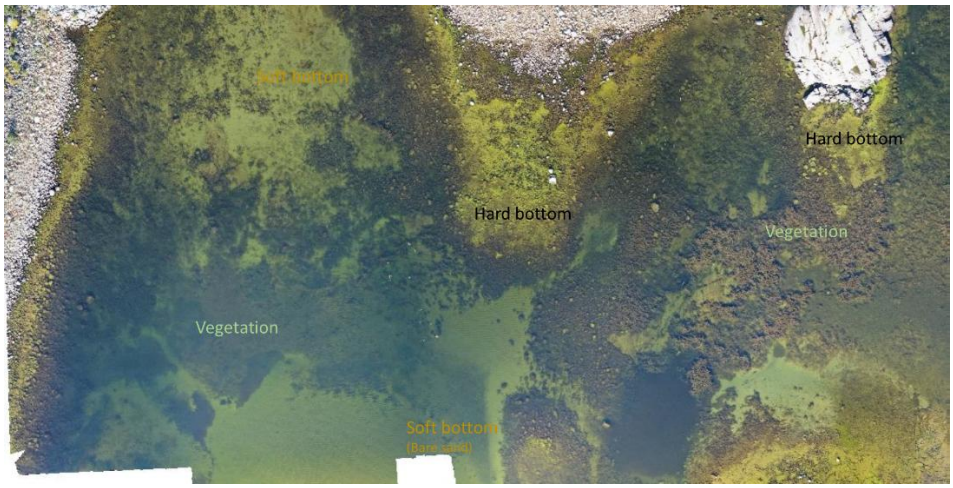


Figure 7. An orthophoto taken under very good weather and water conditions. The water surface is almost invisible and is possible to see the bottom up to a depth of about 5-6 meters.

Weather conditions

Look at a reliable weather forecast and examine the questions:

- Which day and time will it be sunny, is there probability for clouds?
- How does the wind conditions look? If your AOI is exposed, then you must fly when the weather conditions are the best under the day. If the lasts days have been windy then you may have waves.

One tum of rule is to plan your day so that you can fly the exposed areas during the best wind conditions, usually in the morning, and the protected areas later.

Complementary can be important to use near real time information. You can look at apps that you can get near real time forecast, e.g. “Windy”. Then you can follow the weather, e.g. the clouds, at very detailed spatiotemporal scale and decide where to start. This kind of real time plan adjustment will require some experience but give you very good information in those days with suboptimal conditions.

Water conditions

Water conditions play a major role in deciding where it is possible to fly. The easiest way to assess these conditions in near real time is through satellite imagery. The Copernicus Browser provides a user-friendly interface where you can adjust image settings to get a better view of coastal waters (see quick guide in Appendix 1).

If you have several potential flight areas, satellite images help you identify which ones should be prioritized. It is often possible to get a good idea of the conditions several days in advance, or even a week before, especially when the weather has been stable, nu much wind, rain, or very warm periods. The

satellite images leading up to your flight day will usually give a good indication of water clarity.

Before you begin, try to find a historical satellite image with very good water conditions as a reference for compare when you look at the actual imageries. The best way is to open two windows with the Copernicus browser showing the same area. In the first, you scroll image by image and when you see a good image you display it in the second window. We recommend searching across at least two years. When you find good images write down the date. Now you have good images to compare different water conditions in your area and prioritize when and where to fly.

Figure 8 shows examples from different dates with varying water conditions. Image a) represents the best conditions observed over 2–3 years. Image b) shows strong algal blooms, while images c) and d) illustrate brown water caused by humic runoff from a river in the northern part of the area.

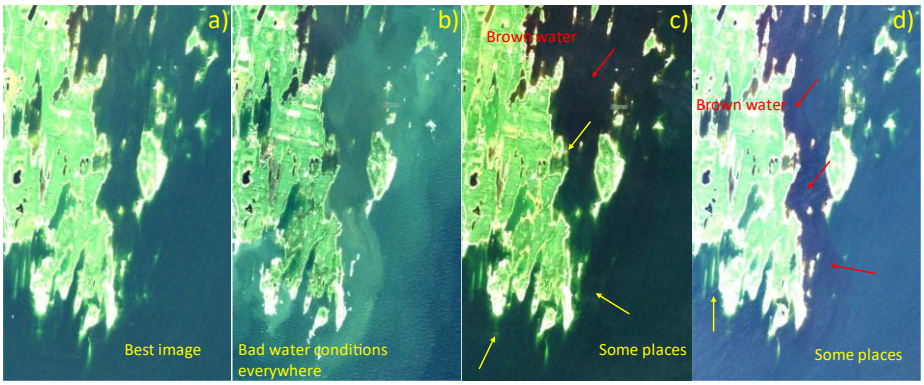


Figure 8. Examples of satellite images under different water conditions.

Figure 9 shows how these conditions affect the feasibility of flying in a specific area. In image a), all areas are suitable for flying. On the other images, the orange polygons represent areas where results are likely to be good but not guaranteed. The red polygons indicate areas where image quality is expected to be too poor for useful results and should therefore be avoided until better conditions occur.

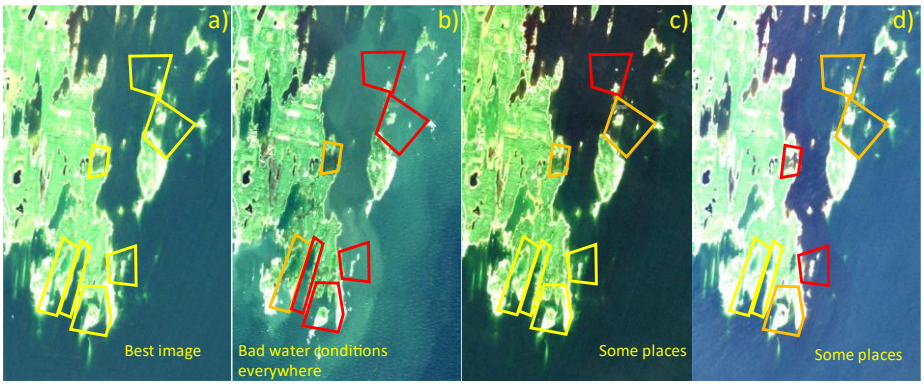


Figure 9. Water conditions on different dates and their implications for flight planning

When you fly despite suboptimal conditions you risk producing images unsuitable for analysis. The problems in your drone images could look like the examples in Figure 10, in which case you will have fly again:

- Clouds (10a) reflected in the water surface are mainly a problem in patchy cloudiness when the clouds stand against a clear sky. The camera can accidentally focus on the mirror image of the clouds, whereby the bottom is not visible.
- Sun glint (10b) can appear as bright bands in the orthomosaic, making it difficult to see the bottom and analyse the image. This can often be reduced by placing the flight transects at a different angle.
- Poor water quality (10c-d) can lead to poor orthophotos where the sea bottom is barely visible.
- The black boxes in the middle of 10c and d indicate problems with putting the orthomosaic together due to the reflection.

None of these examples meet the minimum requirements for an orthomosaic for analysis of bottom habitat and the aerial images must be retaken.

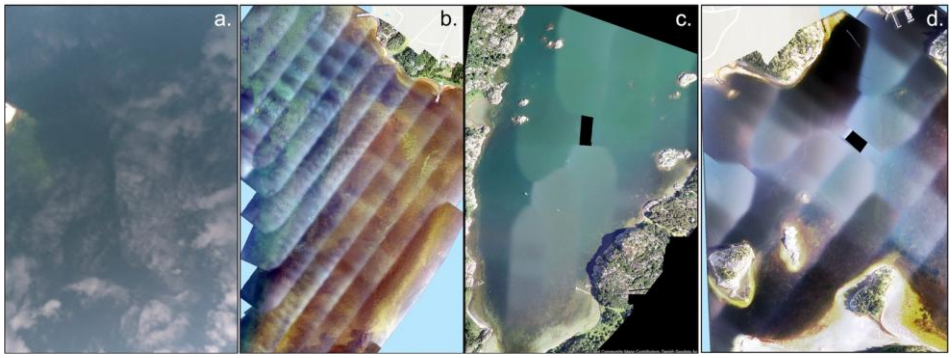


Figure 10 Examples of reflection issues and poor water quality that make orthophotos unsuitable for analysis.

3. Drone flight planning

Flight planning can be carried out directly in the apps that come with the drone controller. It can also be prepared in a GIS tool, where flight areas are drawn as polygons and exported as SHP, KML, or KMZ files, which can then be imported into the flight app. The app will calculate the required number of transects within the polygon based on flight altitude and photo overlap.

Figure 11. Example of transect design and orthophoto. The time of the flight was 10 AM, sun from the northeast, and the transect angle was adjusted to have the sun on the side.

One of the most important aspects of flying over marine areas is to get enough land on the imagery, to facilitate the process of stitching together the orthophotos. If no land is included, it can be very challenging for the photogrammetry algorithm to stitch the orthophoto correctly. Even a small amount of shoreline greatly improves the process.

Camera and drone settings

- Tilt: Defines the camera angle between 0° (horizontal) and 90° (nadir or vertical, opposite of zenith). We recommend nadir but some colleagues report better results with a tilt of 75° and having the sun on back of the camera.
- Drone height: we usually fly at the maximal altitude; 120 m. this gives us a good amount of information for be able to create habitat maps. If the goal is to detect small objects, then you should think about ground sample distance (GSD) or the pixel size in your orthophoto. For most commercial drones, GSD is about 3.5 cm at 120 m.
- Overlap: Defines how much of the photo overlaps the next photo in a series when the drone flies along a predetermined transect.

Recommended starting point: 80% (side overlap)/ 70% (up/down overlap).

- Speed: The default speed of around 10 m/s works well for most situations. Newer drone can take more images per minute and therefore can fly faster. We have not experienced images problems when flying faster in good light conditions. However, in low light, for example, it may be necessary to lower the speed to avoid motion blur. If very sharp images are required for other reasons, speeds below 5 m/s are recommended, which of course increases the total flight time.
- White balance: To prevent colour shifts during the flight, use a fixed white balance, such as Sunny, if available.
- Exposure settings such as shutter speed, aperture, and ISO can initially be set to "Auto" to simplify the process. However, when parts of the area are deeper than approximately 1.5 meters, Auto can cause inconsistent colour between shallow and deep areas (see Figure 12).

  Using Fixed settings avoids this but requires more experience and depends on the light conditions. We recommend testing, but if you fly on a sunny day with slightly deeper part in your AOI, a good starting point is:

  - Shutter speed: 1/200
  - Aperture: ¼
  - ISO: 100.

  If you want to test you can start with the mentioned settings and then fly along the shore and adjust aperture until you get a slightly overexposed image, which improves visibility of the seafloor.

- Choose time shooting if there is a choice between Time shooting and Distance shooting.
- "Distortion correction" should be turned off.

Figure 12. Orthophotos created after having flew with camera settings, a) auto and b) fixed (shutter speed: 1/200, aperture: ¼ and ISO: 100).

Practical problems and recommended solutions

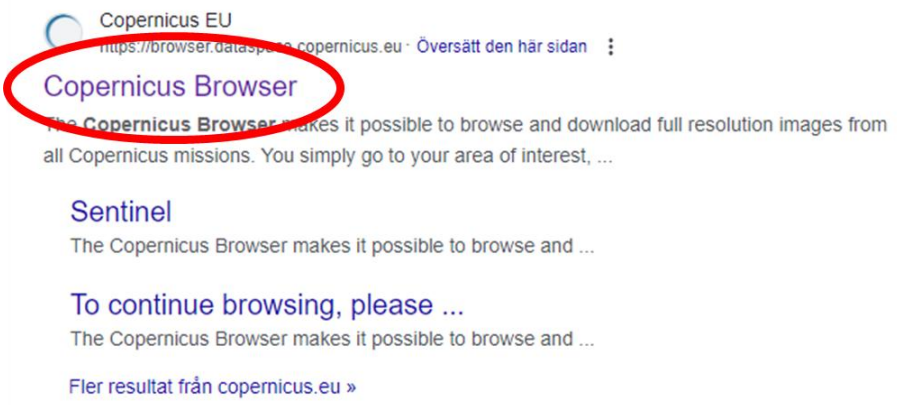
If you need to flight in one area that you expect to have sun glints, you should try to have more overlap to minimize the area in which the orthophoto will be created. Another alternative is to fly above 120 m but then you need another permit to fly drone and probably no a practical alternative.

If you need to flight in presence of some light could, you could use polaroid filters but make sure that the filter doesn't have colour and inform yourself about how the direction of the filter influences the amount of sun glints that could be reduced.

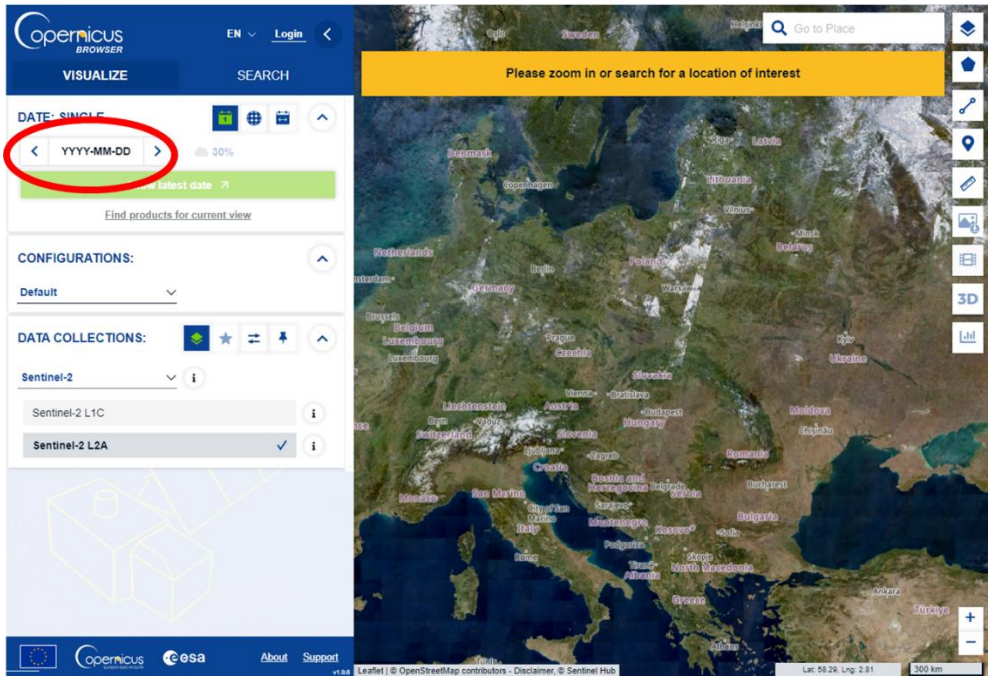
Appendix 1. Quick manual about using Copernicus browser

Go to Copernicus browser website (just google “Copernicus browser”).

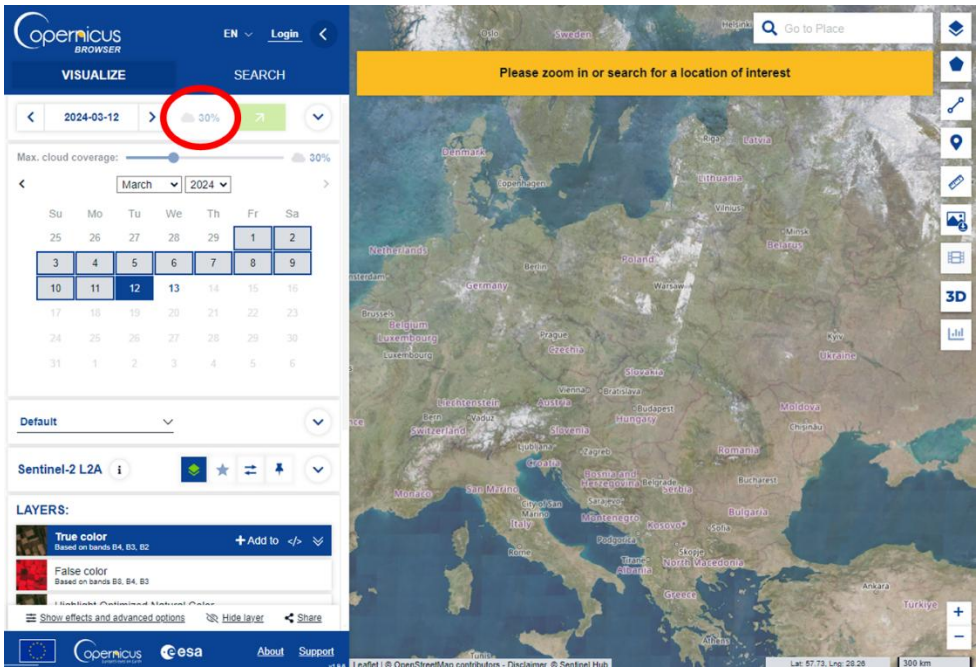
Choose “Copernicus browser”, see below:



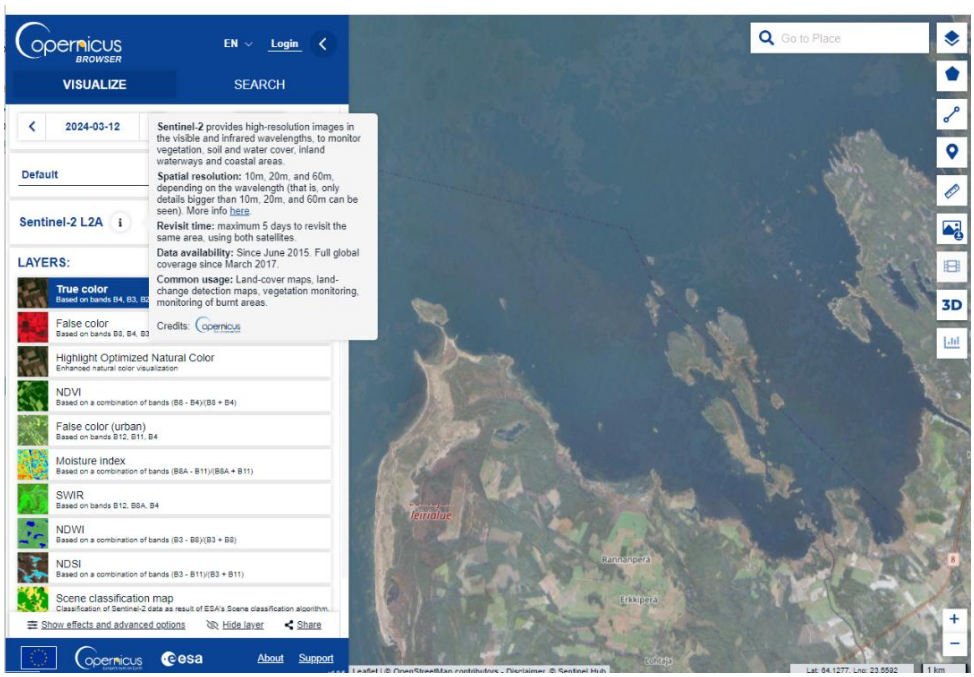
You should see the browser as the image bellow. Start pressing at the date (red circle)



Now you see the available dates. To right of the date you have a filter that hides the images that have more than 30% cloud coverage. You can change it if you don't have images close to your date (maybe from a week before). You will get more images to look at but higher risk that you don't see your AOI because of the clouds.

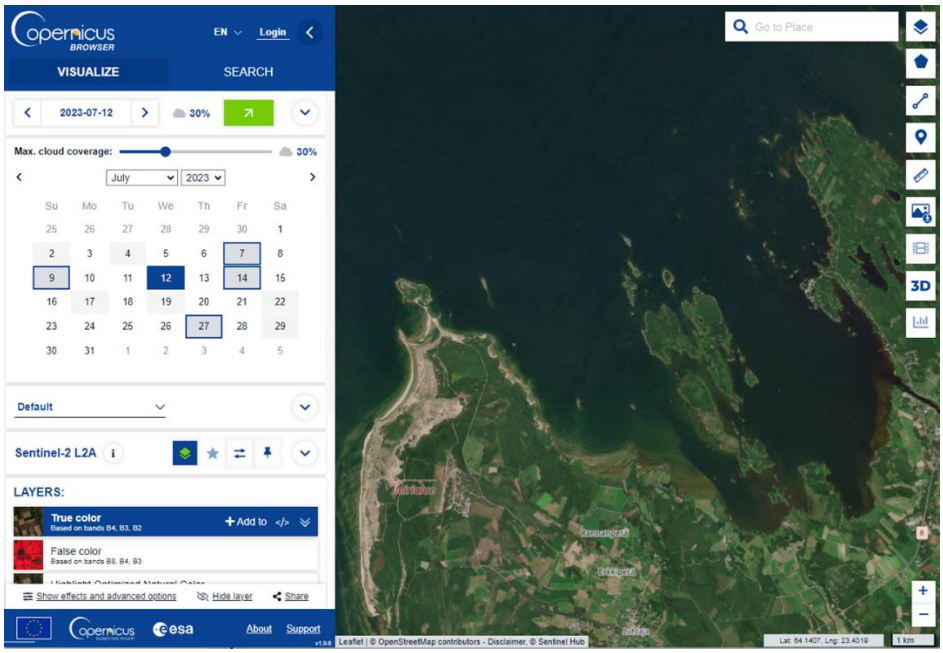


General information



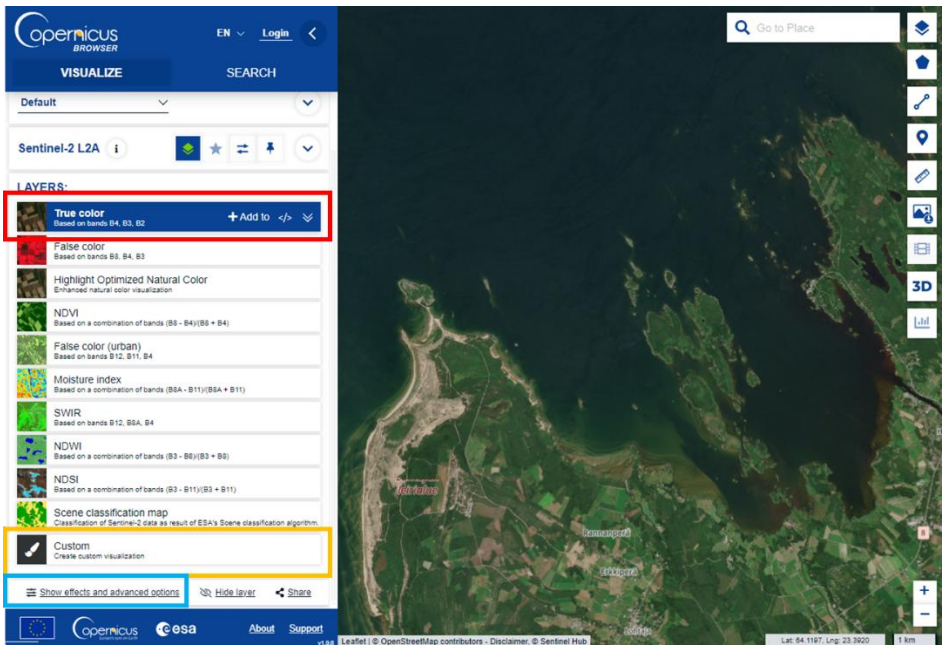
Tips & tricks

Dates in blue rectangles are the available dates without too much cloud coverage. Dates in grey are available dates but with over 30% cloud coverage.

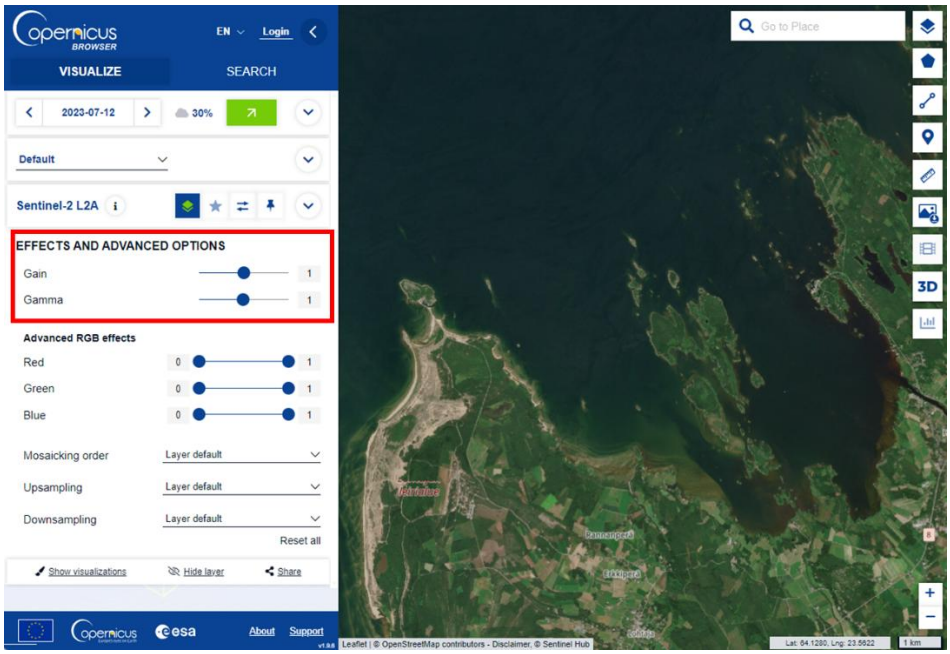


Bands/colour

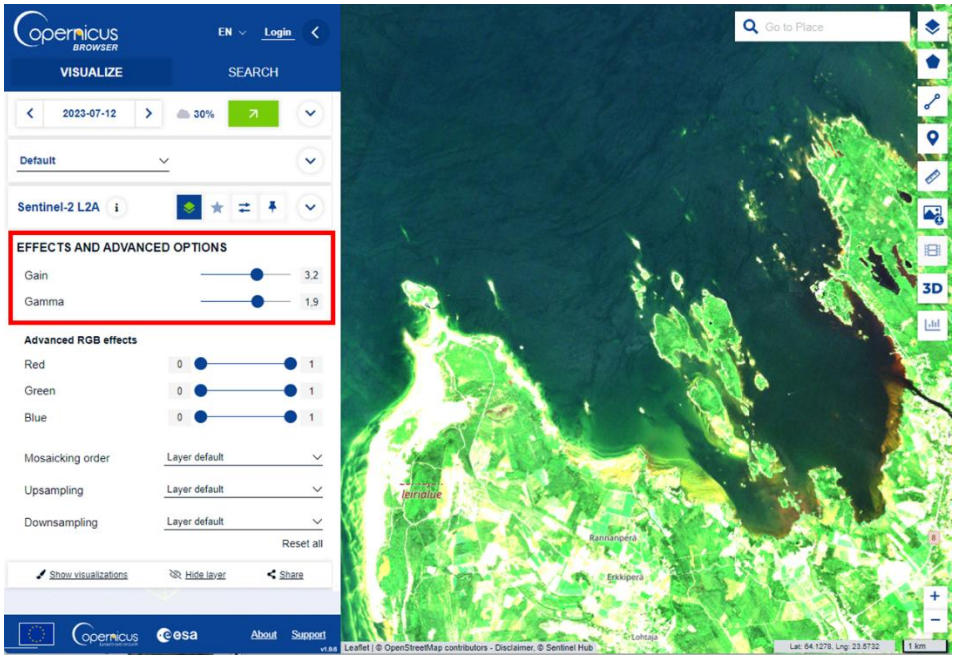
The best is to use true colour (red rectangle) but it is possible to have customized colours (orange rectangle). It is also possible to manage colours under “Show effects and advanced options” (blue rectangle).



Effects and advanced options (red rectangle). Gain and Gamma gives us the possibility to make the image brighter and see the sea bottom better.

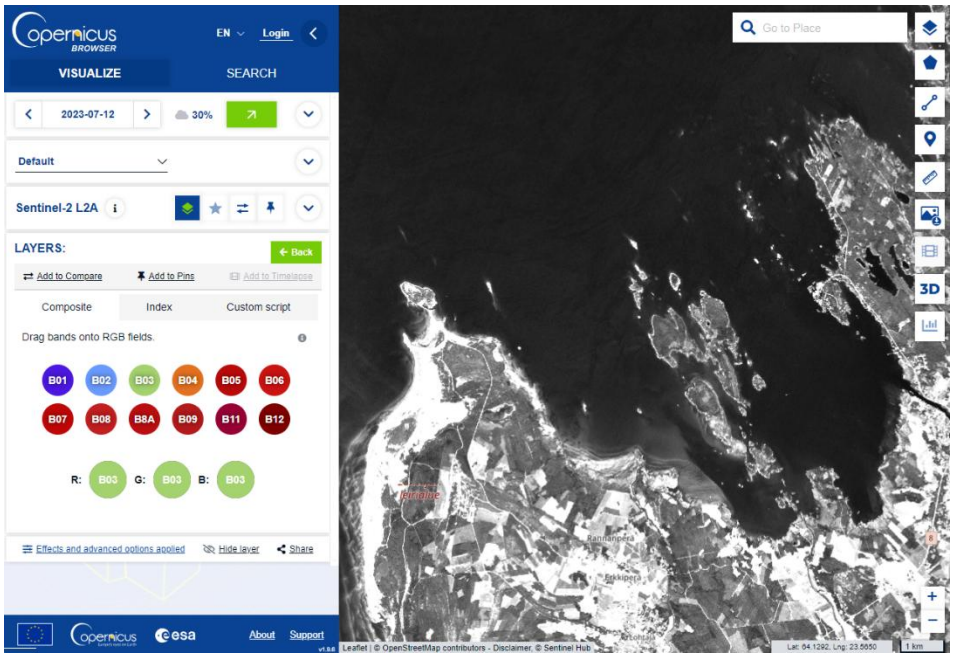


Effects and advanced options (red rectangle). Start with Gain around 3, which results in a very bright image and Gamma value around 1,7, the image gets a little darker. This combination often results in a good colour to show the sea bottom.



Colour

Other ways to see the sea bottom is to use only the green colour, which is the colour that penetrate the water column most in our areas. You can do this under colours and customize. It is then important to change Gain and Gamma to visualize the image in the best way.



Appendix 2. Checklist for fly drones

Before starting the car or leaving home

Equipment

→Drone

→Remote controller

→Fully charged batteries

→Charged phone/tablet

→Charging cables

→Extra SD cards (have always an unopen in the bag you carry your drone)

→Landing pad (optional)

→Sunglasses and sunscreen

→Notebook and pencil

→Calibrate compass (if needed and preferably at least the day before)

→Update firmware (if needed and preferably at least the day before)

Safety & Regulations

→Check local drone laws (EASA, FAA)

→Do not fly over people

→Keep the drone within line-of-sight

→Know emergency return routes

Weather

→Wind less than 8–10 m/s

→Good sunlight

→Low tide (when possible)

→No rain or storms nearby

Final Checks

→Clean the camera lens

→Plan your take-off and landing zone

Before launching the drone:

1.- Take a minute to look at the area.

2.- Identify hazards (birds, boats, power lines).

3.- Set your Return-to-Home height high enough to avoid obstacles.

4.- Double-check battery and GPS signal.

5.- Practice hovering for a moment to see if wind is strong.

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