FINDING OUR WAY IN GREENLAND

with an ice chart web service* and up-to-date satellite imagery

Alex Mansfield and Angie Garz

(*Alex and Angie are new OCC members although they have been following the club for some years. They have been cruising aboard* Twoflower, *their Moody 376, since 2017 and since making an Atlantic circuit in 2020 have been based in the Azores. This summer they joined* Atlas, *a 13m (43ft) ketch, for a voyage to southwest Greenland. The vessel is made available through the Atlas Expeditions association as a platform for research and exploratory expeditions. Visit https:// www.saltytoes.ch to read about their adventures – and learn how* Twoflower *got her name.*

Photos by Alex Mansfield and Angie Garz – Atlas Expeditions unless otherwise credited.)

Weaving through the sea-ice

Our first iceberg appeared as a diffuse whitish smear on the horizon, just about visible against the somewhat greyer fog. It was the harbinger of nearby ice ahead of our bow, which formed increasingly numerous green spots on our radar screen but remained unseen through the fog. This ice from the Arctic Ocean had been carried down and around Cape Farewell by the East Greenland Current. Melted into organic-looking sculptures by the erosive forces of the sun, wind and sea, each piece is unique in colour, shape, size and texture. Sparse at first, the ice grew denser – as we had expected from the ice charts – and we reduced engine revs to give ourselves time to pick our way through. Taking turns on the helm and as lookouts on deck, we steered through narrow leads, pushing away small pieces of ice with our bow wave with growing confidence. Here and there we spied a shy seal peeking out of the water or resting on an ice-floe, and growlers dotted black with guillemots.

* A web service is software on the web that runs on request and provides the results via an internet address.

Atlas in the Arctic ice

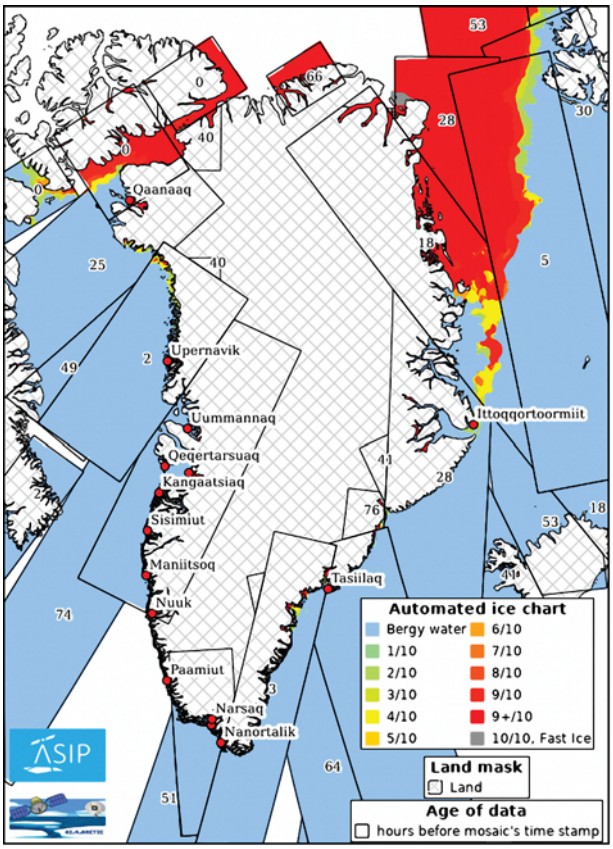
Passing awe-inspiring icebergs in southwest Greenland

As the eventful day faded into evening, we closed with the land and the fog began to lift. It revealed the wild, hilly shore of a fjord filled with sea-ice and bergs – our first glimpse of Greenland. Off the bow and bathed in the warm glow of the low sun, the brightly-coloured houses of Qaqortoq nestled against the slopes that surround its harbour like an amphitheatre. We

Sea-ice sculptures in the fog as we close with the unseen coast

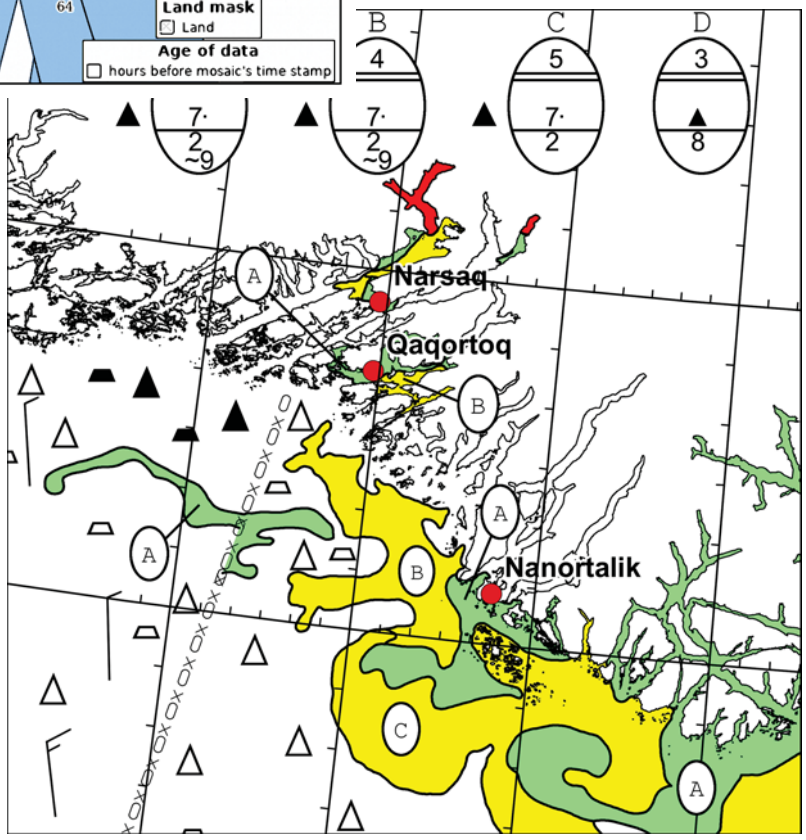
had reached Qaqortoq, the largest town in southwest Greenland and formerly known as Julianehåb, on 19th June 2023, earlier than expected. Until recently this stretch of the Greenland coast was often blocked by ice in June, making it nearly impossible to reach in a small vessel early in the season as Bill Tilman discovered during his voyage to the region in 1970. We had

A harp seal hauled out on the ice. Being hunted, they are wary of boats and people

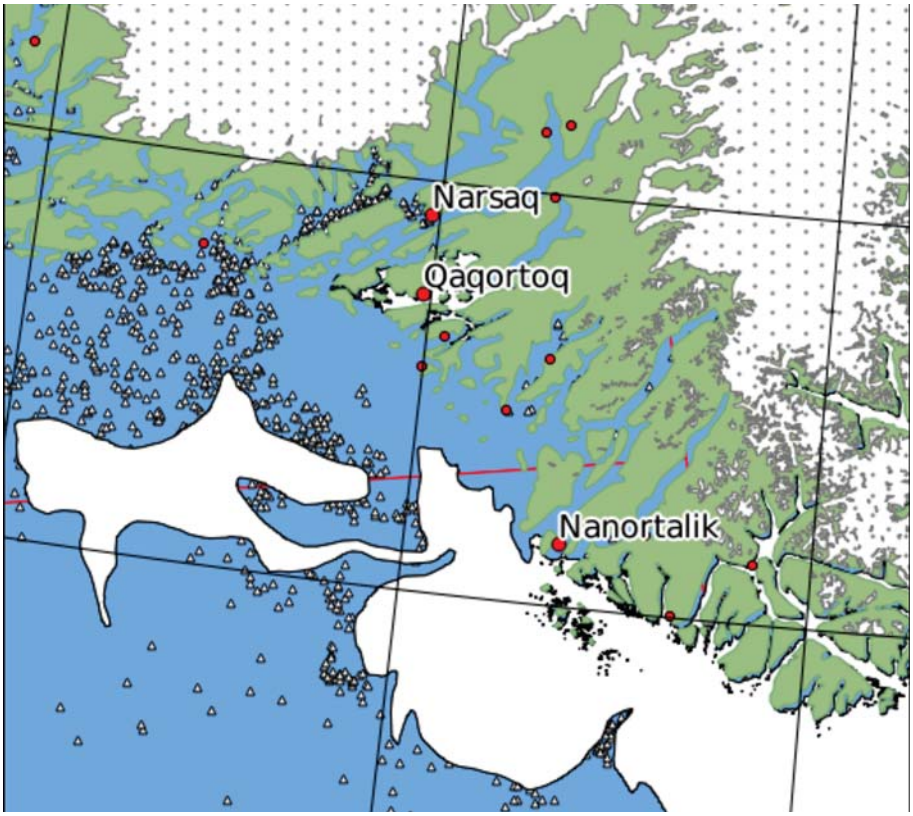


Automated sea-ice concentration mosaic retrieved from the latest available Sentinel-1 radar imagery. Date: 2 October 2023. Courtesy the Danish Meteorological Institute

Opposite: *Part of the Cape Farewell Iceberg Map on the day of our arrival, showing composite data from 12–16 June 2023. The maps are automatically generated from Sentinel-1 radar satellite data. Pure white areas are sea-ice, where iceberg detection is not carried out. Courtesy the Danish Meteorological Institute*



Part of the Cape Farewell Ice Chart of the day of our arrival, 19 June 2023. Egg and colour codes indicate the concentration, stages of development (age) and form (floe size) of the ice. Courtesy the Danish Meteorological Institute



two advantages over Tilman, however – several decades of a warming climate and the ability to receive detailed weather forecasts and ice charts while underway.

We were aboard the sailing vessel *Atlas*, a steel pilothouse ketch with a long keel, designed by Koopmans and built in the Netherlands. Through the Atlas Expeditions association she is made available as a microplatform for scientific and exploratory expeditions. This year *Atlas* was to sail from northern Brittany to the Kujalleq region of southwest Greenland to explore, research and shoot footage for a documentary film. On board were owner/skipper/photographer Arnaud Conne, photographer/film-maker Richard Mardens and the two of us as crew. Later in the season *Atlas* would host a group of speleologists* to explore ice caves under the glaciers, before sailing through Prins Christian Sund to Greenland's east coast. From there she would continue her journey to Iceland, the Faroe Islands and Scotland before ending the season in the Netherlands.

Ice information for Greenland

As we prepared for the voyage we knew that we would need access to the latest ice information as we progressed. Of the many forms of ice information provided for Greenland by the Danish Meteorological Institute (DMI), we particularly wanted the colour versions of the classic ice chart and the iceberg map. The former would allow us to identify areas where we could (or could not) navigate safely, at sea as well as in the fjords, while the latter would reveal in more detail the distribution of larger icebergs.

* Speleology is the scientific study of caves and cave systems.

The harbour at the heart of Qaqortoq, with Atlas tied up to the furthest pontoon

As an additional source of information, we also wanted to get extracts from their new 'automated sea-ice concentration mosaic', which is created from Sentinel-1 radar and microwave satellite data. As with all auto-generated content these must be treated with caution as they can contain errors and biases, although on the plus side they offer more complete coverage of the coastline, allowing us to fill in the gaps between the ice charts.

All these resources are readily available from the DMI's website, but we were not able to find a satisfactory way to retrieve them with Saildocs and Iridium Go! while at sea. There are no direct fixed URLs (permalinks) to the latest charts, and the sizes of the files are relatively large, making for potentially long and frustrating downloads.

The DMI's Ice Service (Istjeneste) generously offers to e-mail the latest black-and-white ice charts as soon as they are issued. However, we found those harder to interpret, particularly within the fjords, as the ice codes are indicated by hatching instead of colours and details can get lost. Furthermore, while the ice charts are the most valuable ice information in the high latitudes, we did not want to miss out on the additional resources mentioned previously. We considered asking a friend for help, but we didn't want to burden them with checking the website daily and manually downsizing the files to send to us.

Web service for retrieving the latest ice information

With a background in programming, we wrote a small web service that allowed us to access small versions of the various ice resources. This web service is a piece of code that runs every few hours and checks the DMI website for the latest information, which it downloads, compresses to make the files smaller and uploads to fixed URLs on the web. In this way, using these permalinks, Saildocs and Iridium Go!, we were able to retrieve the latest charts quickly and easily.

Having access to the latest ice information gave us the confidence to head into Qaqortoq rather than continue further north. This had looked uncertain a few days earlier when the ice concentration had been much denser. That evening, after a glorious day navigating through the majestic ice seascape that we had been imagining for weeks, conjured up from the ice charts, we tied up in the harbour. We had only just shut down the engine and settled in the cockpit to take in the scene when we were greeted by a member of the local boat club. He told us that we were the first sailing yacht to make it through the ice to Qaqortoq this year.

Off the charts, towards the glaciers and into the silt

Peeking through the mist ahead was a small islet, no higher than our mast. As we passed we spotted a pair of white-tailed eagle chicks in their nest on the island's summit. We watched as they tentatively spread their wings in the emerging sun. How long until they fledge and leave the nest? In the distance, two long tongues of the tremendous inland ice sheet reached down towards sea level. This was our destination – the land reborn from beneath the glaciers, released by the retreat of the ice. Bedrock and glacial flood plains criss-crossed by an intricate web of meandering, milky streams laden with glacial flour, rocks crushed and ground into fine powder by the passage of the ice.

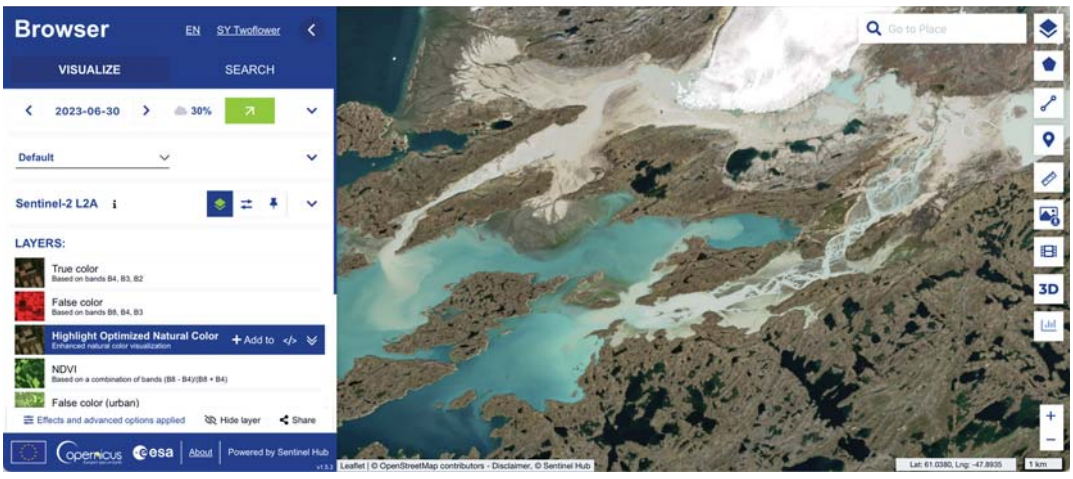
On the chart the soundings were becoming few and far between. Before long we passed off the chart and cautiously proceeded, navigating by eye, depth-sounder and satellite imagery. Still in deep water, in the middle of a wide fjord, we had some more miles to cover before reaching the end of the fjord and our intended anchorage.

The flood plains and moraine landscape revealed by the retreating glaciers fascinated us

Heading up the fjord to the retreated glaciers. Note the reindeer in the foreground

As we continued up the fjord the water colour began to change, becoming increasingly cloudy and silty – a shift we had already seen in the recent satellite images. Our depth-sounder reported a steadily shelving bottom until we had only a little left under the keel. We stopped the boat and looked around. We were still in the middle of this wide fjord, where minutes ago we had had more than 50m below the keel. Was it really so shallow, or was the depth-sounder simply reflecting from sediment suspended in the water? An improvised lead line with a dive weight quickly confirmed the depth-sounder's accuracy!

Copernicus Browser showing the glacial plains a few of days before our visit. In the panel on the left one can select the date, acceptable cloud coverage, the satellite (Sentinel-2 L2A) and the visualisation (Layer). After login, the data can be downloaded with a button on the right of the screen. The platform has many more features, including contrast enhancement, 3D view and time lapse, which can be useful for observing changes. Courtesy the European Union, contains modified Copernicus Sentinel data 2023



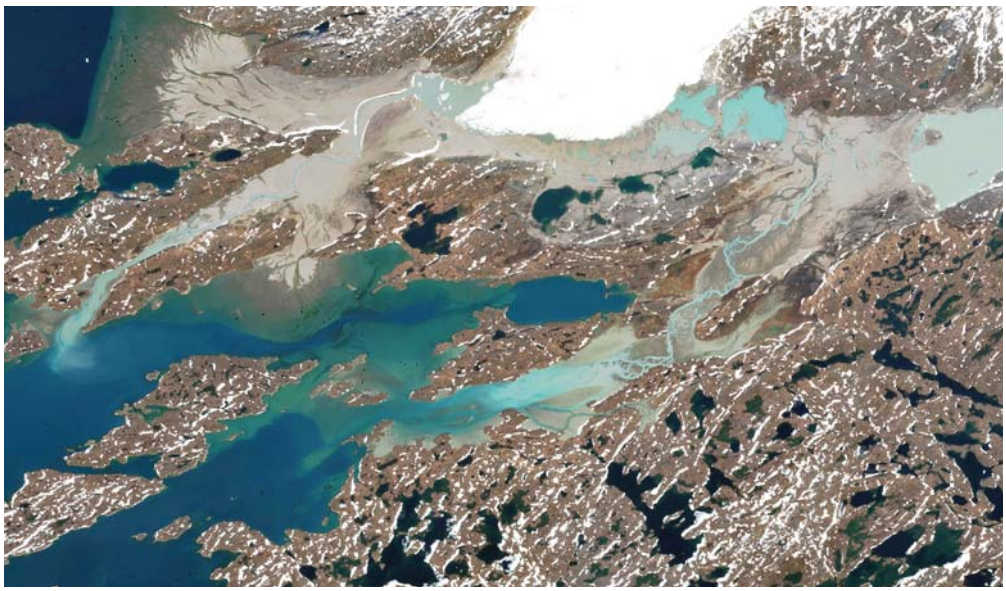
Up-to-date satellite images from Copernicus Sentinel-2

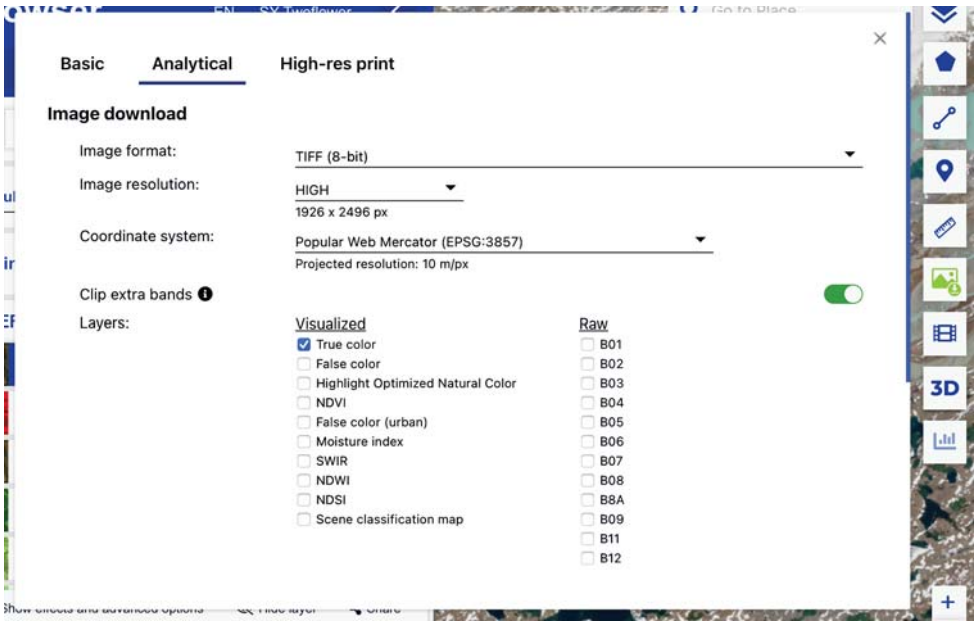
A couple of weeks earlier this fjord had caught our eye as we scoured southwest Greenland via satellite imagery for inspiration about where to explore. We were drawn to the land uncovered by the retreating glaciers with its landscape of rock, tundra and water. We had no chart for the upper reaches of this fjord, however, and looking at different satellite images we could see that it was an area of rapid change, especially in terms of the influx of sediment into the fjord from the meltwater rivers.

While searching for the most recent satellite data available to complement the high-resolution Microsoft Bing Maps we had, we came across the brand-new Copernicus Browser which had been launched only a few days earlier. This platform allows easy access to the very latest Copernicus Sentinel-2 satellite images – the newest often being only a few hours old – as well as an archive of the past images.

Sentinel-2 are twin European polar-orbiting satellites that capture high-resolution multi-spectral images to monitor variability in land surface conditions. Both satellites fly in the same orbit but are phased at 180° so they are always on opposite sides of the planet, shortening the time between overflights. At the Equator new data is available approximately every five days but, due to their orbits, the satellites pass over the mid-latitudes every two to three days and the high latitudes even more frequently. This makes them a particularly interesting source of satellite imagery for high-latitude sailing. Following a free registration, it is possible to filter out imagery with a high percentage of cloud cover and download the geo-referenced images. With the help of the free command-line tool GDAL on Mac we converted those images into the MBTiles format to display as chart overlays in OpenCPN. We haven't tested if the same could be achieved with SAT2Chart or other software.

For comparison, a Sentinel-2 image of the same area on 3rd June 2022, a year before we arrived and before the melting started. The glaciers are covered in snow and, without the additional silt suspended in the water, channels and silt banks are clearly visible. Courtesy the European Union, contains modified Copernicus Sentinel data 2022

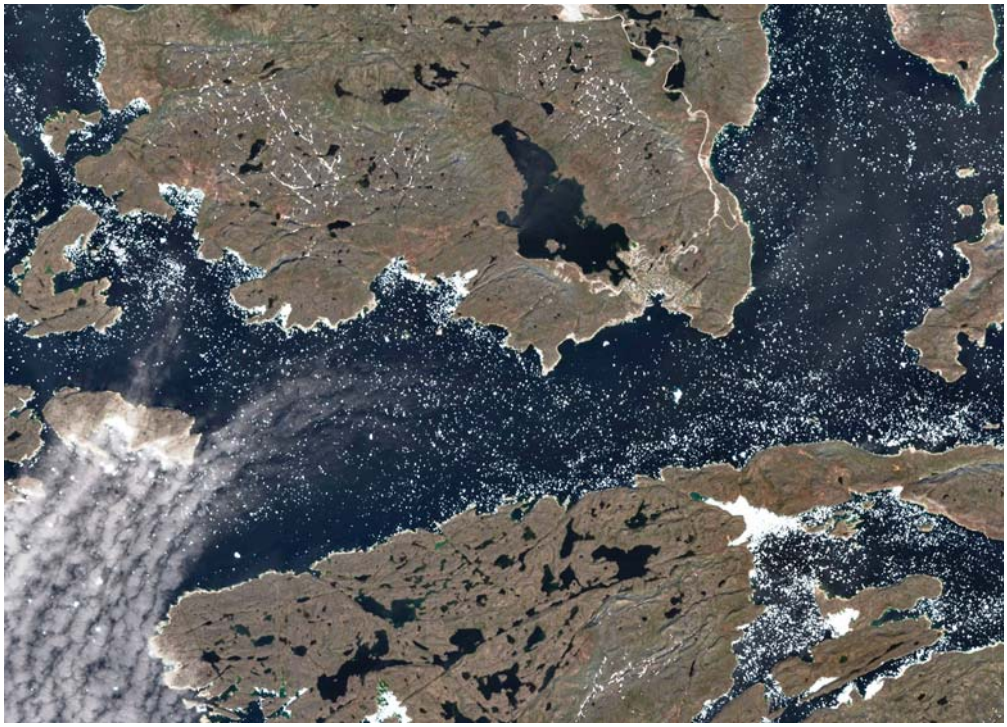




Download geo-referenced TIFF images for conversion to MBTiles for overlaying in OpenCPN using the button highlighted in green on the right. Make sure to select 'TIFF (8-bit)' and high resolution

Comparing the resolutions of Sentinel-2 data (right) and Microsoft Bing Maps (below). The details of the latter are far superior for seeing the lie of the land, but are composites of many images of unknown date

Courtesy the European Union, contains modified Copernicus Sentinel data 2023. Microsoft product screenshot(s) reprinted with the permission of Microsoft Corporation



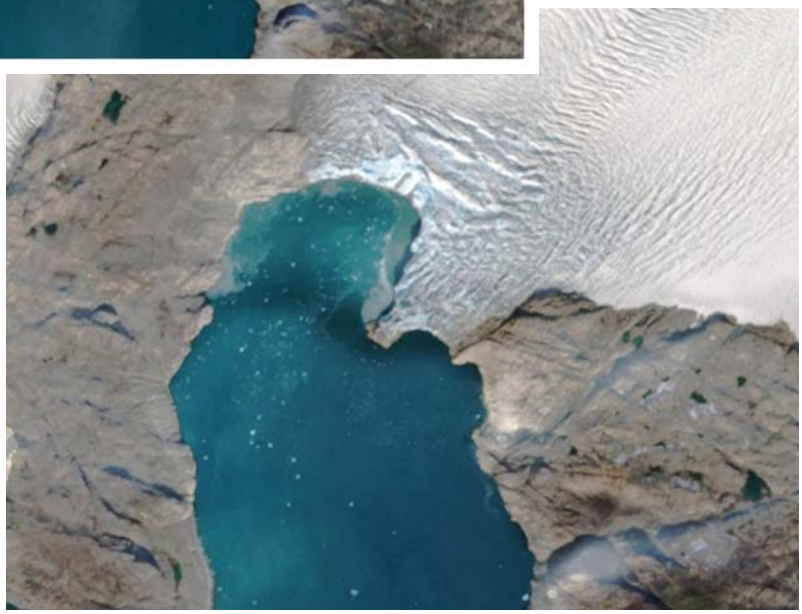
A Sentinel-2 satellite image showing ice in the waters around Qaqortoq on 18th June 2023, the day before we arrived. Courtesy the European Union, contains modified Copernicus Sentinel data 2023

The excellent article *Using Satellite Imagery with OpenCPN* by Sherry and Dave McCampbell on page 47 of this *Flying Fish* describes using Google Earth, Microsoft Bing Maps and other sources in a similar way. Satellite images from these sources are composites, created every few years by combining many images taken over time to create clean, cloud-free and highly detailed imagery. In contrast the Copernicus Sentinel-2 images are lower resolution, but only a few hours or days old. They are captured at a single instant in time like a photograph and allow you to look at an area in the present. Using the archive of past images you can also look backwards in time to see how the area has changed.

In practical terms, satellite imagery from Google Earth and co is best at showing semi-permanent features such as coastlines, reefs and patches of sand or weeds in an anchorage, and as such is akin to nautical charts. The satellite images from Copernicus are more like ice or weather analysis charts – they provide information that is most relevant right now, such as the positions of glacial ice fronts and shifting sandbanks and silt. Indeed, they can also be used to see sea-ice concentrations, providing an interesting complement to the ice charts. Both types of satellite images must be used with due caution, as stressed by the McCampbells in their article.

Further up the fjord

We quickly learned to identify the navigable water by comparing the water colour in the Sentinel-2 images with the depth-sounder readings. This would not have been possible



Sentinel-2 satellite images of a retreating ice front in southwest Greenland, June 2020 and September 2023. Courtesy the European Union, contains modified Copernicus Sentinel data 2020 and 2023

with the Bing imagery. We realised we could not reach the end of the fjord with *Atlas* as we had intended, but could make our way around a bar of sediment and anchor behind it. From there we launched the dinghy to continue towards the glaciers.

As we passed between two islands we were astonished to see a small group of reindeer sharing the fjord with us, the water barely reaching halfway up their legs. They were clearly as surprised and curious as we were and came splashing towards us for a closer look at three figures in a rubber dinghy. Close to low tide, this part of the fjord was so silted up that it allowed the reindeer to walk between the mainland and the various islands. While the reindeer made for the next island we continued on our way. Soon we, like the reindeer, had to walk, water lapping at our rubber boots as we pulled the dinghy behind us.

Next steps

Our voyage to Greenland and the specific challenges of navigation there compelled us to seek out and use the additional sources of information we have described. We are convinced that both the web service we developed and the use of up-to-date satellite imagery could have great potential for cruising in many areas of the world. We are very happy to share more details about what we did with other members and to receive feedback and ideas. Would making our web service more widely available, providing ice charts, satellite images and other information in small file sizes, be useful to you? Do you know of other information that is currently hard to access via satellite connection which you would like to see included? Would you like to work together with us, to contribute ideas, resources and code? Look us up in the *Members Handbook*, on the OCC app or in the online Membership Directory and get in touch. We look forward to hearing from you.

Links

Atlas Expeditions – https://atlasexpeditions.org

DMI Ice Service (Istjeneste) – https://www.dmi.dk/gronland/is/kontaktoplysninger/

DMI ice charts – https://www.dmi.dk/gronland/is/

DMI iceberg maps – http://polarportal.dk/en/sea-ice-and-icebergs/icebergs/

DMI automatic ice concentration mosaic – https://ocean.dmi.dk/asip/

Copernicus Browser – https://dataspace.copernicus.eu/browser/

GDAL – https://gdal.org/

Saildocs – http://www.saildocs.com

Curious reindeer splashing towards us through knee-deep water