

This image, captured by the Copernicus Sentinel-2 mission on October 10, 2021, shows a new flow of lava from the Cumbre Vieja volcano erupting on the Spanish island of La Palma. The image has been processed in true colour, using the shortwave infrared channel to highlight the lava flow.

Image: ESA

## GEO MANAGEMENT TEAM

### General Information

John Tellick,  
email: [information@geo-web.org.uk](mailto:information@geo-web.org.uk)

### GEO Newsletter Editor

Les Hamilton,  
email: [geoeditor@geo-web.org.uk](mailto:geoeditor@geo-web.org.uk)

### Technical Consultant (Hardware)

David Simmons  
email: [tech@geo-web.org.uk](mailto:tech@geo-web.org.uk)

### Webmaster and Website Matters

Vacancy  
e-mail: [webmaster@geo-web.org.uk](mailto:webmaster@geo-web.org.uk)

### Management Team

David Anderson  
Rob Denton  
Nigel Evans: [nigel.m0nde@gmail.com](mailto:nigel.m0nde@gmail.com)  
Clive Finnis  
Carol Finnis  
Peter Green  
David Simmons  
David Taylor

## Useful User Groups

### Weather Satellite Reports

This group provided weekly reports, updates and news on the operational aspects of weather satellites.

<https://groups.io/g/weather-satellite-reports>

### SatSignal

This end-user self help group is for users of David Taylor's Satellite Software Tools, including the orbit predictor WXtrack, the file decoders GeoSatSignal and SatSignal, the HRPT Reader program, the remapper GroundMap, and the manager programs - MSG Data Manager, GOES-ABI Manager, AVHRR Manager etc.

<https://groups.io/g/SatSignal>

### MSG-1

This forum provides a dedicated area for sharing information about hardware and software for receiving and processing EUMETCast data.

<https://groups.io/g/MSG-1>

### GEO-Subscribers

This is the official group is for subscribers of the Group for Earth Observation (GEO), aimed at enthusiasts wishing to exchange information relating to either GEO or Earth Observation satellites.

<https://groups.io/g/GEO-Subscribers/>



Tiger

Follow GEO on  
**Facebook**



**facebook**

Visit GEO on facebook and link to dozens of news items from NOAA, NASA, ESA, EUMETSAT and much more ...

<http://www.facebook.com/groupforearthobservation>



# From the Editor



Les Hamilton

Thanks to welcome contributions from several readers, we have a super 40+ page edition of the *Newsletter* for you this quarter. There are two offerings from Ed Murashie, one describing the Sally Ride EarthKAM, which is mounted on the International Space Station. Ed explains how you can book time slots to image your chosen region of the planet using it. Secondly, Ed embarks on the first part of a triple feature on the Landsat series of satellites, in this issue detailing how they came to fruition.

Richard Fairman describes how he overlays Met Office charts upon Meteor M2 Rimagery while Richard Osborne writes about visualising of EUMETCast SAF products. There's also an interesting update about the continued progress of the Dundee Satellite Station from Neil Lonie.

The startling cover image on this issue relates to the ongoing eruption of the Cumbre Vieja volcano on the island of La Palma in the Canaries. At the time of publication, the eruption had been ongoing for over ten weeks with no end in sight, and is described in features on pages 17 and 19. Additionally there is the usual eclectic mix of articles from NASA and ESA which will hopefully entertain you through the dark winter nights.

Finally, we wish every reader our very best wishes for the Festive Season and the New Year ahead.

---

## Contents

Zuiderzee Works	NASA Earth Observatory	4
Record-breaking Year for Fire in Sakha	NASA Earth Observatory	5
The Sally Ride EarthKAM	Ed Murashie	7
Sea Ice forming in Kuskokwim Bay	MODIS Web Image of the Day	10
Rio de la Plata	MODIS Web Image of the Day	11
Manually Decoding Historic Meteor M2 S-files in MeteorGIS	Les Hamilton	12
Looking Up - Looking Down	Robert Moore	15
Shark Bay	MODIS Web Image of the Day	16
Ash and Cloud Rings Over La Palma	NASA Earth Observatory	17
La Palma Volcano: How Satellites help us Monitor Eruptions	European Space Agency	19
Overlay Met Office Pressure Charts on Meteor M2 Images	Richard Fairman	21
Ice Persists in the Northwest Passage	NASA Earth Observatory	24
Sahara Dust Cloud over Europe	MODIS Web Image of the Day	25
LANDSAT: The Satellite That Might Save the Earth	Ed Murashie	26
NASA, USGS Release First Landsat 9 Images	NASA	31
Progress update: Dundee Satellite Receiving Station	Neil Lonie	32
The Caspian's Shallow North	NASA Earth Observatory	34
Springtime on New Zealand's South Island	MODIS Web Image of the Day	36
Visualising EUMETCast SAF products	Richard Osborne	38
Colorado River Delta	MODIS Web Image of the Day	37
Satellite Status		46

# Zuiderzee Works

**NASA Earth Observatory**

*Story by Emily Cassidy*



NASA image by Alan Holmes/NASA's Ocean Color Web, using data from SeaHawk/HawkEye.

*Details overleaf*

## Zuiderzee Works (continued from previous page)

Where the Netherlands meets the North Sea there is an impressive confluence of natural and man-made features. Much of the human-made infrastructure is designed to keep rising seas out of the low-lying country. The landscape carved by nature is a hotspot for plants and animals taking advantage of the nutrient-rich wetlands.

The Netherlands has long been shaped by floods and by efforts to hold back the sea. A spine-like archipelago known as the West Frisian Islands protects the mainland of the country. Just to the south lies the world's largest system of unbroken mud flats, known as the Wadden Sea. Harbour seals, Eurasian spoonbills and some 10,000 other species of flora and fauna depend on these mudflats for migration and feeding.

The Wadden Sea used to be connected to the bay to its south—known as the Zuiderzee—until the construction of the 32-kilometre Afsluitdijk in 1932. Designed to protect the Netherlands from rising seas, the dam also created a freshwater lake known as Lake IJssel.

Cutting part the Zuiderzee from the North Sea allowed the Dutch to reclaim some of the shallow wetlands behind the dam. The Ministry of Infrastructure and Water Management surrounded the wetlands east of Amsterdam with dykes and drained them for agriculture using wind power: land reclaimed in this manner is known as a polder. Roughly 1,620 square kilometers of land has been

reclaimed this way. Collectively, this human-made system of dams, dykes, and polders is known as the **Zuiderzee Works**.

The Wadden Sea provides a critical resting and feeding place for millions of birds as they make their yearly migration along the East Atlantic Flyway. Since 2009 the area has been listed as a World Heritage Site by the United Nations Educational, Scientific and Cultural Organization because of its unique ecology and importance to biodiversity.

The image above was acquired on June 1, 2021, by the multispectral *HawkEye* sensor aboard the *SeaHawk* CubeSat. *SeaHawk* is a new nanosatellite designed to monitor phytoplankton by measuring the colour of the ocean and coastal ecosystems. Phytoplankton are the foundation of food webs in marine ecosystems and they also play a large role in the global carbon cycle by consuming about 24 percent of the carbon dioxide in the atmosphere.

Previous satellite instruments designed to measure global ocean colour, such as the Sea-viewing Wide Field-of-view Sensor (*SeaWiFS*) had lower spatial resolution and the large pixels made research of marine and coastal environments challenging. *SeaHawk* was designed to fill this void by providing data with eight times the spatial resolution of *SeaWiFS*. This small satellite only recently began routine operations but has already proven to be a low-cost way to measure ocean colour in coastal ecosystems.

## A Record-Breaking Year for Fire in Sakha

**NASA Earth Observatory**

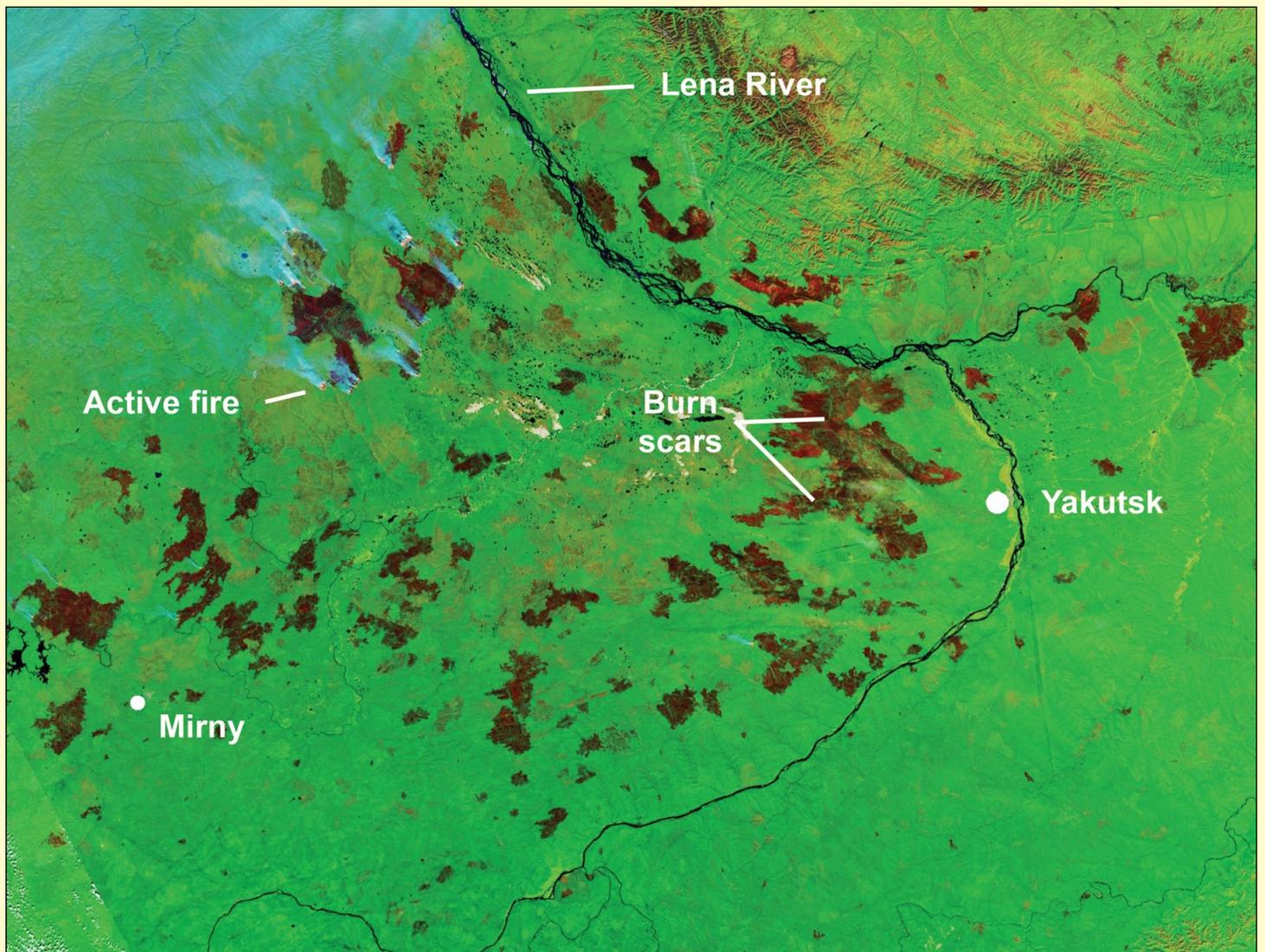
Story by Adam Voiland

The larch forests of the Republic of Sakha (Yakutia) are like no other place on Earth. Found in a region with some of the world's largest seasonal temperature swings, these boreal forests are dominated by a deciduous conifer called *Larix gmelinii*. This hardy type of larch is capable of withstanding temperatures as low as  $-70^{\circ}\text{C}$  and surviving in frozen permafrost soils—traits that have given the tree the most northerly range on the planet.

In summer 2021, huge fires raged through these larch forests for months. During Sakha's most severe fire season in decades, more than 8.4 million hectares of forests burned. *'That's an amazing amount—nearly four times the average,'* said Amber Soja, a NASA and National Institute of Aerospace associate research fellow who has conducted field research in the region. It's also record-breaking. More forest area burned in Sakha than in any year since the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite began collecting data in 2000.

In the false-colour satellite image overleaf, burned areas appear dark brown; unburned areas are green. Patches of green within burn scars are fire refugia—areas within fire perimeters that were unburned or only lightly burned. The Visible Infrared Imaging Radiometer Suite (VIIRS) on the Suomi NPP satellite captured the image on September 10, 2021.

*Details and image overleaf*



NASA Earth Observatory image by Lauren Dauphin, using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview.

For a sense of scale, Sakha is almost twice as large as Alaska, the largest U.S. state, and five times larger than Madagascar.

*‘What happens in Sakha, and in boreal forests more broadly, matters tremendously,’ said Soja. ‘Boreal forests store more carbon than any other type of forest in the world—even more than tropical rainforests.’*

*Larix gmelinii* drops its needles each winter, but the weather is so cold that there are few decomposers (bacteria, fungi, invertebrates) around to break them down. That means tremendous amounts of organic carbon end up accumulating in soils over time.

*‘Many of the fires here burn for a long time—weeks even months. Some have burned the same areas in multiple years,’ explained Soja. ‘These fires aren’t just spreading across the landscape, they’re also burning downward. They’re thawing permafrost, burning through layers of peat in some areas, and releasing stored carbon and methane that has built up over millennia.’*

Outbreaks of large fires in Sakha have happened before, including 2004, 2010, 2013, 2019, and 2020. The 2019 and 2020 fire seasons were particularly extreme in Sakha’s tundra regions north of the Arctic Circle. As this area baked under extreme drought and heat, it experienced the two earliest and largest fire seasons on the satellite record.

In 2021, there has not been nearly as much burning north of the Arctic Circle; instead more of the fires occurred in forests farther south. *‘We saw a different part of Sakha burn this year,’ Soja said. ‘But the underlying driver—droughts and heat amplified by climate change—was the same.’*

# The Sally Ride EarthKAM

*Ed Murashie*

Imagine being a student and being able to command a camera onboard the International Space Station (ISS) four times a year to take a picture. That is not a dream but the reality of the *Sally Ride EarthKAM* program. If you're a teacher or have kids or grandkids going to school this is something you should consider. If that is not the case, you can still enjoy and download the images the students receive. Best of all this is all free!

The KidSat payload was a pilot program sponsored by NASA's *Office of Human Resources and Education*. It was announced on October 11, 1995 by NASA's Jet Propulsion Laboratory (JPL). KidSat principal investigator, Dr. JoBea Way of NASA JPL, stated in the initial press release that:

*'KidSat will be designed, built and operated by students' and 'the underlying philosophy of this program is to stimulate young people's interests in learning by giving them their own piece of the space program.'*

Former astronaut Dr. Sally Ride, a professor of physics at University of California San Diego stated:

*'By attaching KidSat to the Space Shuttle, students will be able to participate in space exploration as astronauts and cosmonauts do'.*

Ride was leading the development of the mission operations element of KidSat with NASA's Johnson Space Center <sup>[1]</sup>.

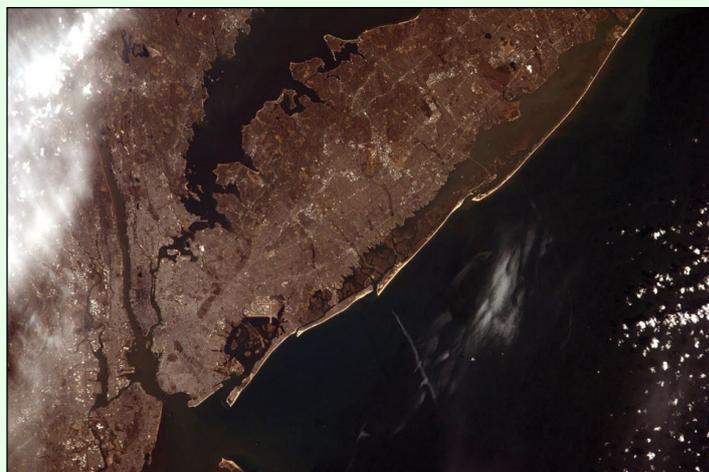
KidSat was truly a student-lead project with the students working at JPL being responsible for the flight system and computer software. Undergraduate and high school students manned the mission control center at the University of San Diego and were responsible for linking the school requests with the shuttle flight controllers. Students at Johns Hopkins University Institute for the Academic Advancement of Youth were responsible for the classroom curriculum.

Three schools participated in the first KidSat mission during shuttle mission STS-76 which launched on March 22, 1996. The payload was again flown in 1997 on both STS-81 and STS-86 with more participating schools than before. Prior to the next mission, the payload was renamed *EarthKAM*, an acronym for *Earth Knowledge Acquired by Middle school students* <sup>[2]</sup>. EarthKAM flew on shuttle missions STS-89, STS-93, and STS-99 in 1998, 1999, and 2000 respectively <sup>[3]</sup>. The hardware consisted of a Nikon digital camera mounted in

the shuttle's overhead window, connected to a *Thinkpad* computer which was in turn connected to the shuttle's communication's system. Requests from the schools were routed to the *Thinkpad* which controlled the camera taking the images.

When the United States International Space Station Lab Module *Destiny* was added in 2001, EarthKAM was moved to that platform and has been a part of every ISS Expedition since Expedition 2. In 2010 the system was reconfigured and placed in the Window Observational Research Facility (WORF) <sup>[4]</sup> rack in the floor of the module. You can use *Google Earth* to take a tour of the ISS to see the WORF system for yourself. In the Destiny Module, the WORF system is partially located under a black cloth used to block stray light. Simply go to **[earth.google.com](http://earth.google.com)**, click the magnifying glass, enter '*International Space Station*', click on the *Guided Tours* tab, click on *Visit the International Space Station*, and finally click on *U.S. Laboratory Module*.

**Sally Ride passed away in 2012 and in 2013 NASA renamed the program Sally Ride EarthKAM in her honor.**



EarthKAM image image showing New York

The current ISS hardware consists of a Nikon D2X camera with either a 50 mm or 180 mm lens connected to a laptop computer running the *EarthKAM* software. The 50 mm lens provides an image 35 miles on either side of the ground track while the 180 mm lens provides 11 miles. It is the 'ground system', a computer and web browser, in the classroom, that makes the program highly educational and easy to use.

To participate a school needs only to follow the numbered steps on the EarthKAM main webpage <sup>[3]</sup>. First, a teacher signs up once for the program and then signs up for a mission. During a mission they

[Reset map] KEY Day Night

Map Satellite

Software calculated the best ISS location to take the picture is here

Mouse clicked here for desired location

1315

Google Keyboard shortcuts Imagery ©2021 NASA, TerraMetrics Terms of Use

Set your location: Latitude  °  N  S Longitude  °  E  W Go ?

Current mouse position: 14.19° N, 37.26° E

Distance from Groundtrack ? 160.47 mi (258.26 km) **This should be < 10 mi**

Step 3: Make your image request using the information below.

Image Request Info

Orbit	1315
GMT	2021/197/16:55:44

This is the Sally Ride EarthKAM's 'Select Location' screen.

sign into the *Mission Operation Center* webpage and request one or more images. When the images have been taken and uploaded to the website, the students can download and optionally annotate them it and order prints. To learn more you can follow one of several *YouTube* videos <sup>[5]</sup>, my recorded presentation during the Satellite Educators Association Conference <sup>[6]</sup> or the steps outlined below.

The first step, creating an account, is nicely labeled as *Step 1* on the EarthKAM home page. Click on it and fill in the school information and how it will be used in the classroom.

If no upcoming mission has been announced, now is a great time to either explore the learning activities by clicking on **Activities** in the top homepage menu bar, or to learn how the whole process works by clicking on the **Help button** and then clicking on the **Sally Ride EarthKAM User Guide** <sup>[7]</sup>. Each activity, ranging from learning about orbits to how to interpret the EarthKAM images, includes a teacher guide along with a student handout. Even if you only did one activity a day there are weeks' worth of activities to keep the students busy and learning.



EarthKAM image of Russia's Amur river in winter

When a mission has been announced the teacher signs up to receive 250 codewords to be handed out to the students. One codeword is needed for each image requested and more codewords can be requested.

### Making the Request

When the mission starts, each student participating should fill out a **Mission Targeting Sheet** found on the **Help webpage** for each image they would like to request. To request an image, the student signs into the **Mission Control Center** and then clicks on the **Weather tab** to check out the weather in the area of interest. They certainly don't want a clouded image, unless of course they are interested in taking a picture of clouds or a hurricane. Next they click on the **Image Request tab** and then **select the orbit** that is closest to their target. The student needs to determine the exact time when the ISS is closest to their target so they can enter that time into the image request. To do this they move the cursor on the map to their target and see a red target on the orbit track following close by. The red target indicates the ISS' best position to take an image of the target.

The student can either place the cursor over a city or land feature, or they can use the plus and minus buttons to zoom in and explore the map leaving their cursor on an interesting feature and make note of the nearest city. The students must verify that the distance between the chosen location and the ISS is less than 10 miles to guarantee their location is within the image even if the 180 mm lens is used. Next, they click on the **Request Image button**, enter one of their codewords, the orbit number, the GMT time, latitude and longitude from the **Image Request Info box** under the map along with the city location, and a reason for this request. The city and reason help other people looking at their image to understand what they found interesting about this location. Finally they click the **Submit button**.

The **Welcome tab** webpage will display the image requests and status. When the status changes to 'Taken' the student can view the images on the School Gallery webpage.



EarthKAM image taken over the Netherlands

Anyone can always click on the EarthKAM homepage **Images tab** and then the **Visit the Gallery** [8]. From there you can visit themed, annotated, or all the images from specific missions. When you click on an image you will find information about the image including the school that took it. From there you can download the image, view it on Google Earth, or print it out.

And did I mention—all this is free?

### References

- 1 <https://www.jpl.nasa.gov/news/students-prepare-new-kidsat-payload-to-fly-on-space-shuttle>
- 2 [https://www.nasa.gov/mission\\_pages/station/research/experiments/explorer/Investigation.html?#id=87](https://www.nasa.gov/mission_pages/station/research/experiments/explorer/Investigation.html?#id=87)
- 3 <https://www.earthkam.org/>
- 4 <https://www.youtube.com/watch?v=SdbFn9DOzRg>
- 5 <https://www.youtube.com/watch?v=qYXHleZBalk>
- 6 [https://www.sated.org/conferences/conf34pics/Murashie\\_Presentation.htm](https://www.sated.org/conferences/conf34pics/Murashie_Presentation.htm)
- 7 [https://www.earthkam.org/files/pdf/ISS\\_EarthKAM\\_User\\_Guide.pdf](https://www.earthkam.org/files/pdf/ISS_EarthKAM_User_Guide.pdf)
- 8 <http://images.earthkam.org/main.php>

At their highest resolution, images from the EarthKAM show great detail. As an example, download this image of Little Italy, Melbourne, Australia, acquired during November 2021 from

[http://images.earthkam.org/main.php?g2\\_itemId=1804225](http://images.earthkam.org/main.php?g2_itemId=1804225)

and zoom in to see the detail.

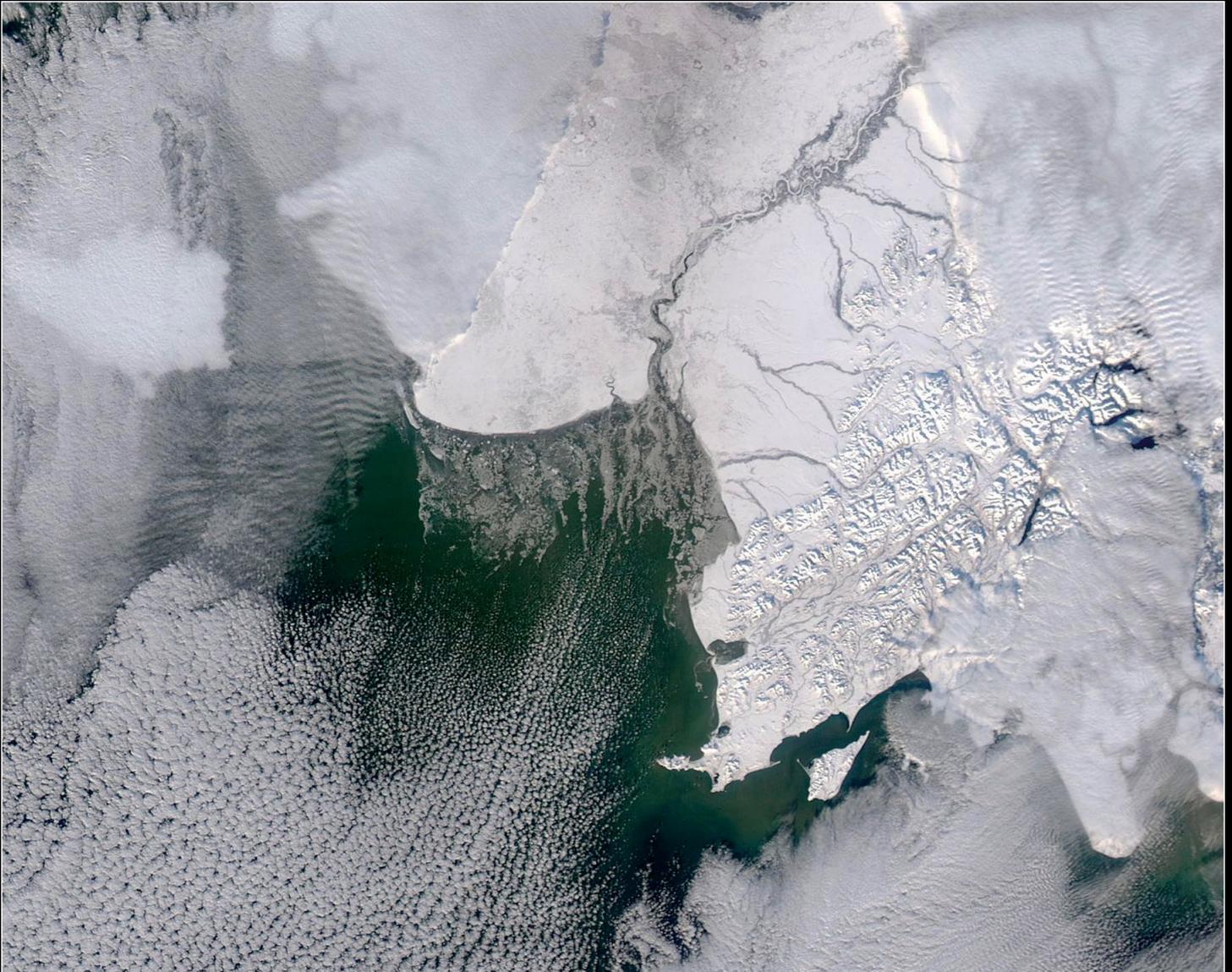


This is a small section of the 'Little Italy' image acquired by EarthKAM, showing urban detail.

# Sea Ice forming in Kuskokwim Bay

**MODIS Web Image of the Day**

<https://modis.gsfc.nasa.gov/gallery/showall.php>



*Image Credit: MODIS Land Rapid Response Team, NASA GSFC*

Fresh ice off the coast of southwestern Alaska shimmered in the sunlight of an autumn day in early November 2021. The Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Aqua satellite acquired this true-colour image on November 11.

The icy fingers stretch across Kuskokwim Bay, a large embayment of the Bering Sea. It receives freshwater from several rivers, especially the large Kuskokwim River, a glacially turbid river that originates in the Kuskokwim Mountains and travels approximately 900 miles through remote territory to reach the Bay. The drainage basin that flows into the river is the second-largest in the state of Alaska. The river typically ices up in mid-November, when sea ice also begins to form in the Bering Sea. This year, frigid temperatures near the ground arrived early and the annual expansion of sea ice is well underway. The rapid river ice-up stranded a barge that was carrying building

materials down river to Eek, a town of about 400 people in a remote area not far from the Kuskokwim River. In late October, as the barge turned towards the Eek River, a rapid drop in temperature brought a sudden freeze up of the river, obstructing the barge's movement. It is planned to leave the barge in place overwinter and return to recover it in spring.

The *National Weather Service* reports that the sea ice minimum for the entire Arctic occurred on September 16, with the overall sea ice extent in Alaska farther south than most of the last 10 years. The transition from ice shrinking to expansion is well underway, but the report states that new growth has been confined to the ice edge and is limited by sea surface temperatures. The sea surface temperatures in the northern Bering Sea were cooler than recent years, spurring a less-delayed start of freeze-up in this region.

# Rio de la Plata

*MODIS Web Image of the Day*



The Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Terra satellite acquired this true-colour image on September 16, 2021, in the waning days of winter.

*Image Credit: MODIS Land Rapid Response Team, NASA GSFC*

This stunning true-colour image captures the dramatic colours created by the mixing of muddy river water with the clear, but saline water of the South Atlantic Ocean. This mixing occurs in Rio de la Plata, the muddy estuary of the Paraná and Uruguay Rivers, which forms part of the border between Argentina and Uruguay. The rich estuary supports both capital cities of Buenos Aires, Argentina and Montevideo, Uruguay. These cities

appear as gray pixels on the south shore and the north shore of Rio de la Plata. Buenos Aires is the larger city.

The Paraná is South America's second longest river and drains much of the southeastern part of the continent. The extensive delta of the Paraná nearly reaches across the mouth of the Uruguay River. The rivers' fertile soils support extensive agriculture, including livestock, in

the region surrounding the cities. As the rivers course through the landscape, they accumulate large amounts of sediment, which dumps into the estuary along with fresh water. The complex mixing pattern creates beautiful colours, with sediment floating near the surface appearing in shades of tan. As sediment sinks below the surface, the reflectivity changes and this causes the colour to trend towards green when seen from space.

# Manually Decoding Historic Meteor M2 S-files for MeteorGIS

Les Hamilton

The *MeteorGIS* software package authored by Christophe Marchand has rightly become extremely popular on account of its ability to process images from Russia's Meteor M2 satellite in a variety of ways, most specifically by creating geospacially corrected images to which overlays of coastlines, country outlines and major cities may be added.

But *MeteorGIS* did not appear until late 2019, more than five years after the Meteor M2 satellite was launched and commissioned. A question that has been raised a number of times on the internet, and also to me personally, is this: 'Can historic Meteor S-files dated before *MeteorGIS* was available, be processed by the software'.

Although the documentation within the MeteorGIS package suggests that this is possible, no-one to my knowledge seems to have satisfactorily mastered this: or if they have, they have been keeping very quiet about it. This prompted me to carry out some experimentation, and though the process is somewhat contorted, it can be done! All you require is a Meteor M2 S-file, a manual version of *LRPT Decoder* and a two-line keplerian element set for the date on which the S-file was acquired. The various stages that have to be accomplished are listed below.

## 1 Modifying the S-file

Historic S-files, created by LRPT Decoder, typically have the date/time format shown below.

**2020\_03\_22\_LRPT\_08-53-37.s**

There is a problem here, because *MeteorGIS.exe* does not recognise this format, which is characteristic of S-files created by Vasili Beriakov's Meteor plugin for SDRsharp. To enable data to be retrospectively decoded by MeteorGIS, all underscores must be replaced by hyphens, and the fragment 'LRPT\_' deleted altogether, leaving a filename that contains solely the date/time values, as follows.

**2020-03-22-08-53-37.s**

After editing an S-file accordingly, copy it into the S\_file folder within your *MeteorGIS* package.

## 2 The Required M2\_Man\_LRPT\_Decoder ini file

The ini file for the manual version of *LRPT Decoder* within the *MeteorGIS* package must contain a section headed '[GEO]' so that a GCP (Ground Control Points) file related to the S-file can be created. The data in this file is used by MeteorGIS to geospacially modify the decoded Meteor channel images. The basic LRPT Decoder ini file structure

```
[IN]
sat=M2
source=man
mode=72k

[OUT]
rgb=123.jpg
rgb_q=100
mono=yes
logs=no
APID70=no
VCDU=no
path=C:\Meteor\Images_M2

[GEO]
RoughStartTimeUTC=22/03/2020
TleFileName=C:\Meteor\M2_tle.txt
Alfa_M2=110.8
Delta_M2=32.0
Alfa_M22=110.0
Delta_M22=-4.8
```

The recommended structure for the M2\_Man\_LRPT\_Decoder ini file

is shown in the grey panel above. Note that the **RoughStartTimeUTC** (date) must be identical with the date section (highlighted in red) of the S-file, although the format is different: in both cases, the date referred to here is March 22, 2020.

Also, the satellite is specifically designated as 'M2' rather than 'auto'. I find that archived S\_files won't decode under the 'auto' setting in manual mode, hence the need to be specific.

## 3 Keplerian Elements

Unless you have saved the then current Meteor M2 keplerian elements from the date of acquisition, you will have to source these from the internet. The best option is Space-Track at

<https://www.space-track.org/auth/login>

If you haven't already done so, create an account, which is a simple matter of entering a username and password (both of your own choices).



Once you have done so, Space-Track opens showing the screen at right. Click the link: **Retrieve ELSET Data by Satellite Catalog Number** to advance to the 'Historical Elset Search' screen. The catalogue number for Meteor M2 is 40069, which is inserted under 'Entries'.

All that remains is to select the appropriate date range for your S-file. Note that entering the same date in the 'From' and 'To' windows achieves nothing. The two dates must be different to encompass at least one complete 24-hour interval. In the screenshot below, selecting from June 10 to June 12 will download all relevant element sets for Meteor M2 for both June 10 and June 11.

I recommend this because sometimes keplers for the date of the S-file don't work. In this eventuality, the previous day's keplers will usually be found to do the trick. I don't understand why this should be. Perhaps there is a conflict between Universal Time, under which the kepler sets are listed, and Local Time which defines the Meteor acquisition.

Once the dates are entered, click the 'Load Data' button and the keplerian element sets will be listed at the foot of the screen. Most days, several such sets are listed.

In practice, it's best to start one day prior to the desired date and continue to one day afterwards. This will download kepler sets for both the day in question and the previous day. The screenshot at right shows result between June 10 and 12, 2015, with the sets of keplerian elements listed below in the grey panel.

If you need to check which date is which, refer to the two values underlined in red. The first two digits (15) represent the year (2015) while the last three digits indicate the day of the year. You can determine the date for an element set by referring to the **Day-Of-Year Calendar** at

<https://www.esrl.noaa.gov/gmd/grad/neubrew/Calendar.jsp>

as illustrated for June at right. This shows that day 161 is June 10 and Day 162 is June 11.

Now that the data are available, carefully copy lines 1 and 2 of a dataset and edit them into the **M2\_tle.txt** file. A common cause of failure is to copy a line 2 followed by a line 1: line 1 must come first with line 2 below it!

Welcome
Box Score
SATCAT
Decay/Reentry

### ELEMENT SET (ELSET) DATA

Retrieve ELSET Data by Satellite Catalog Number

[Bulk Catalog Data Downloads](#)

[TLE Format Description](#)

[CCSDS OMM Standard](#)

### HISTORICAL ELSET SEARCH

**Entries**

**SORT BY**

NORAD\_CAT\_ID

EPOCH

Descending

**EPOCH**

Latest

Date Range

**From:**

**To:**

[LOAD DATA](#)

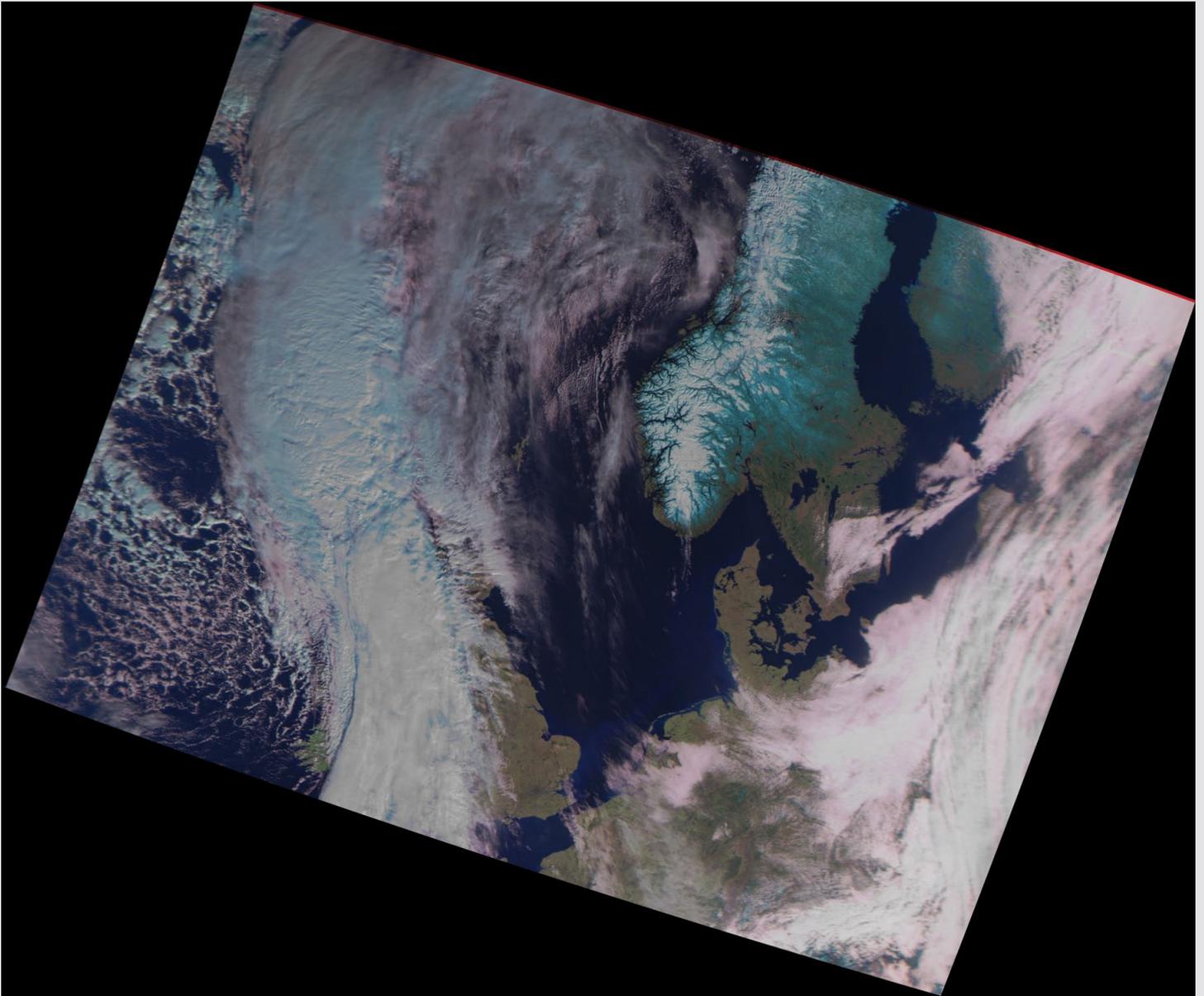
**API** [https://www.space-track.org/basicspacedata/query/class/gp\\_history/NORAD\\_ASC/EPOCH/2015-06-10--2015-06-12/format/tle](https://www.space-track.org/basicspacedata/query/class/gp_history/NORAD_ASC/EPOCH/2015-06-10--2015-06-12/format/tle)

```

1 40069U 14037A 15161.11579291 .00000005 00000-0 22632-4 0 9997
2 40069 098.7569 215.8184 0005688 171.4828 188.6462 14.20610326 47766
1 40069U 14037A 15161.46795237 .00000009 00000-0 24661-4 0 9993
2 40069 098.7568 216.1674 0005702 170.4353 189.6936 14.20610428 47818
1 40069U 14037A 15161.74968016 .00000009 00000-0 24562-4 0 9991
2 40069 098.7570 216.4467 0005731 169.3834 190.7458 14.20610432 47858
1 40069U 14037A 15162.10184013 .00000014 00000-0 26776-4 0 9994
2 40069 098.7567 216.7956 0005743 168.6321 191.4995 14.20610534 47909
1 40069U 14037A 15162.45399976 .00000014 00000-0 27037-4 0 9999
2 40069 098.7566 217.1446 0005770 167.6658 192.4663 14.20610589 47957
1 40069U 14037A 15162.80615953 +.00000008 +00000-0 +24400-4 0 9998
2 40069 098.7568 217.4936 0005802 166.5292 193.6030 14.20610533048001

```

JUNE 2015						
SUN	MON	TUE	WED	THU	FRI	SAT
	1 152	2 153	3 154	4 155	5 156	6 157
7 158	8 159	9 160	10 161	11 162	12 163	13 164
14 165	15 166	16 167	17 168	18 169	19 170	20 171
21 172	22 173	23 174	24 175	25 176	26 177	27 178
28 179	29 180	30 181				



This Meteor M2 image dates from March 11, 2015, and has been retrospectively processed using MeteorGIS

#### 4 Processing

To start processing your Meteor M2 images make sure that

- the **S-file** has been converted to the correct format and is placed in the S\_files folder. This guarantees that the three decoded Meteor channel images will be in the correct format to be recognised by MeteorGIS and processed correctly.
- the **M2\_tle.txt file** has been updated with the correct keplerian elements
- **RoughStartTime** in ManualLRPTDecoder.ini has been updated with the date shown in the S-file

and you are set to go.

- Load the S-file into LRPT Decoder and watch the greyscale images building up on screen. Most early Meteor S-files use the 72k bit rate but if this fails try again with 80k (some early trials used 80k). The three Meteor channel images and stat files will be saved in the Images\_M2 folder, just as in a 'live' acquisition.

Note at lower left on the screen, it states 'GEOGRID will be calculated'.

- As soon as processing is complete, click the

**Generate RGB button** and the text changes to 'Calculating' accompanied by a counter.

This is the process that creates the GCP file, but at this point only in memory. To save the gcp file along with the images and stat files, you must now click **Save** in the top menubar and select **JPEG**.

Don't select BMP because this will not save the essential gcp file.

- The final step is to dive into the MeteorGIS folder and double-click the **default.bat** file (or the Manual\_M2\_GIS.bat file - they are identical) to create the 'Treated' and 'UTM' Meteor images and save them in the FinalImages folder..

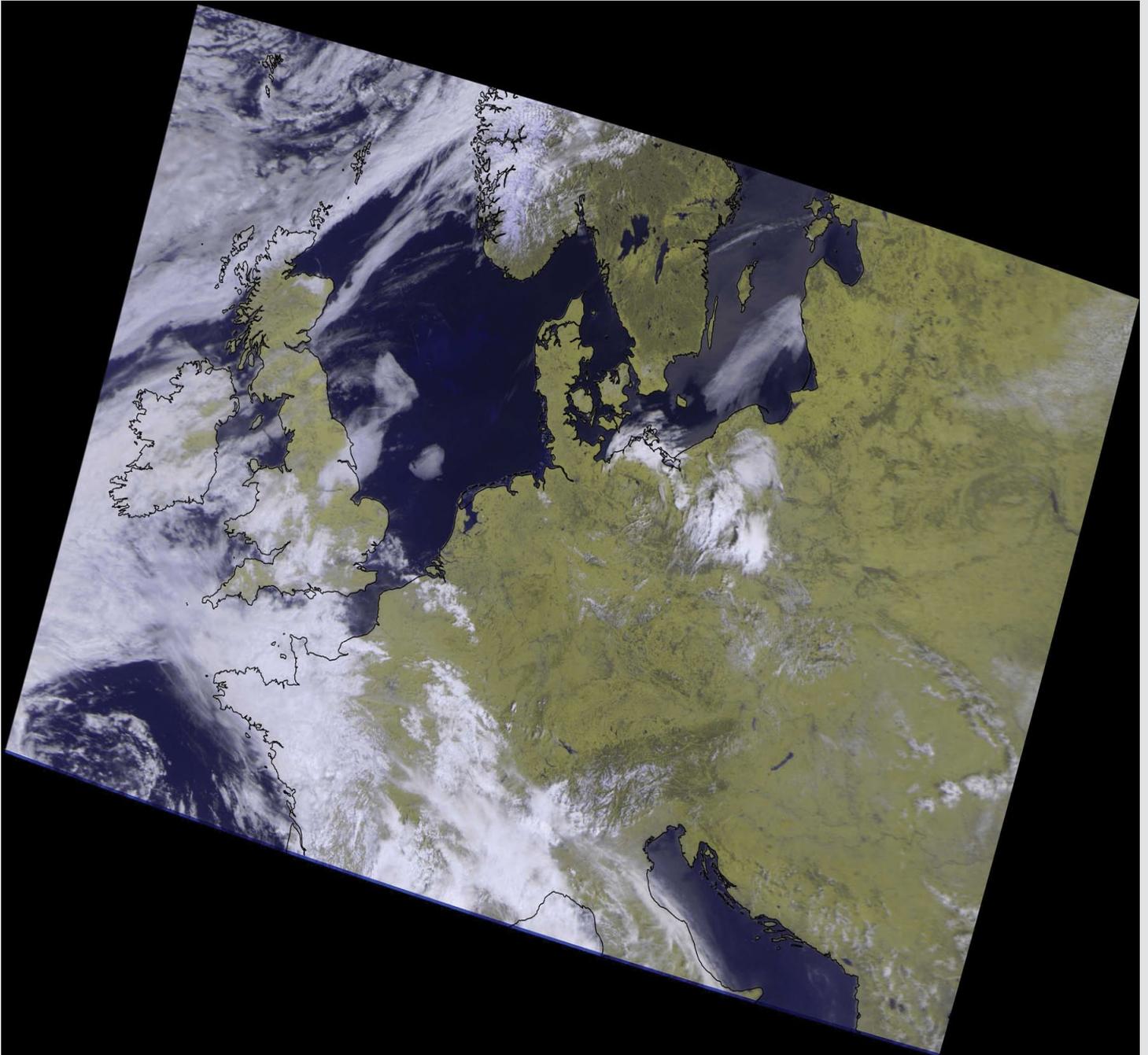
#### Terminology

All names used above are as found in the portable Meteor GIS suites available from my website at

<http://leshamilton.co.uk/MeteorGIS.htm>

Hopefully, for users who have set up their own MeteorGIS systems from scratch, the above explanation is sufficiently clear for them to implement it if so wished.

**A more detailed explanation of this process is available on my website at the following URL**  
<http://leshamilton.co.uk/ReprocessGIS.htm>

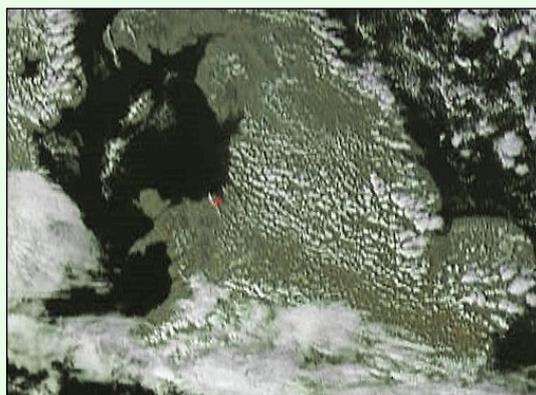


This Meteor M2 image dates from June 13, 2015, and has been retrospectively processed using MeteorGIS

## Looking up - Looking down

*Robert Moore*

There were very distinct cloud streets over Lancashire at 1415 on October 15, as seen in the image from MSG-4. Since I could see these streets from my window, I took a photograph. The tiny red marker shows my location on the satellite image. The photo was taken facing to the north-east and the buildings on the horizon are in Bootle and Liverpool.



MSG-4 image of cloud streets above Lancashire at 14:15 UT on October 15, 2021.



A photograph of the cloud streets taken a few minutes after reception of the MSG-4 image.

# Shark Bay

*MODIS Web Image of the Day*



Image Credit: MODIS Land Rapid Response Team, NASA GSFC

Long before William Dampier—an English explorer, pirate, and natural historian—first set eyes on the rich waters and bays he dubbed ‘Shark Bay’, the wondrously biodiverse area was well known to local indigenous peoples. According to the *Shark Bay World Heritage Site* web page, the local Malanga Aboriginal peoples called this area Gutharraguda, a word meaning ‘two waters’—and an apt description of two protected bays formed by a pair of nearly parallel peninsulas found off the far western Australian coastline.

Sitting about 820 kilometres north of Perth, Shark Bay looks a bit like the letter ‘W’ when viewed from space. Edel Land Peninsula and Dirk Hartog Island lie together along the western reaches, with limestone cliffs that rise steeply along the Indian

Ocean on the peninsula and sandy dunes on islands. Perron Peninsula sits in the center and houses tidal flats in the west and rusty red-sand dunes in the east. Hamelin Pool is found Between Perron Peninsula and the mainland coast.

Shark Bay has become famous for its biodiversity, especially the massive underwater meadows of seagrass which stretch across the eastern shore and include 12 of the world’s 60 known seagrass species. The Wooramel seagrass bank is the largest on Earth, spanning 1,000 square kilometers along Shark Bay’s eastern coastline. Probably the most unusual and fascinating forms of life here are stromatolites—layered rocks that are created when microbes trap particles and create sediments. The stromatolites found here are some of the most diverse in the world.

# Ash and Cloud Rings Over La Palma

NASA Earth Observatory

Story by Adam Voiland

Since the Cumbre Vieja volcano began erupting on September 19, 2021, most of the compelling activity has happened on the ground. For nearly two weeks, thick sheets of lava burned through farmland, roads and homes on the southwestern part of La Palma, one of the Canary Islands.

The atmospheric effects of the eruption had been less dramatic until the Canary Islands Volcanology Institute (INVOLCAN) reported an increase in explosive activity that started on October 2. In the midst of the elevated activity, the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's **Terra** satellite captured an image (figure 1) of a dense plume of ash streaming south on October 4, 2021. According to the *Toulouse Volcanic Ash Advisory Center*, the plume reached three kilometres on October 4, posing a hazard to aircraft in the area. Despite the increase in activity, volcanologists still rank Cumbre Vieja's explosivity as 'moderate', a 2 out of 8 on the *Volcanic Explosivity Index*.

The eruption has not been energetic enough to inject large amounts of ash and gases into the stratosphere, where they can have strong and lasting effects on weather and climate. However, it has been strong enough to produce a rising column of emissions that helped form the remarkable pattern in the clouds shown in figure 2, acquired by NASA's **Aqua** satellite on October 1, 2021.

The bullseye-shaped cloud was the product of a rising column of superheated ash and gases known as the eruption column. The buoyant column of water vapour and other gases rose rapidly upward until colliding with a drier, warmer layer of air at roughly five kilometres altitude. The unusually warm air above—a temperature inversion—functioned like a lid, preventing the volcanic plume from rising any higher. Instead, it flattened out and spread horizontally.

Since volcanic eruptions typically have natural ebbs and flows in their intensity, pulses in the upward flow of the volcanic column created concentric gravity waves as they hit the temperature inversion and spread outward. The process is similar to the way a stone dropped in a pond creates ripples that spread outward.

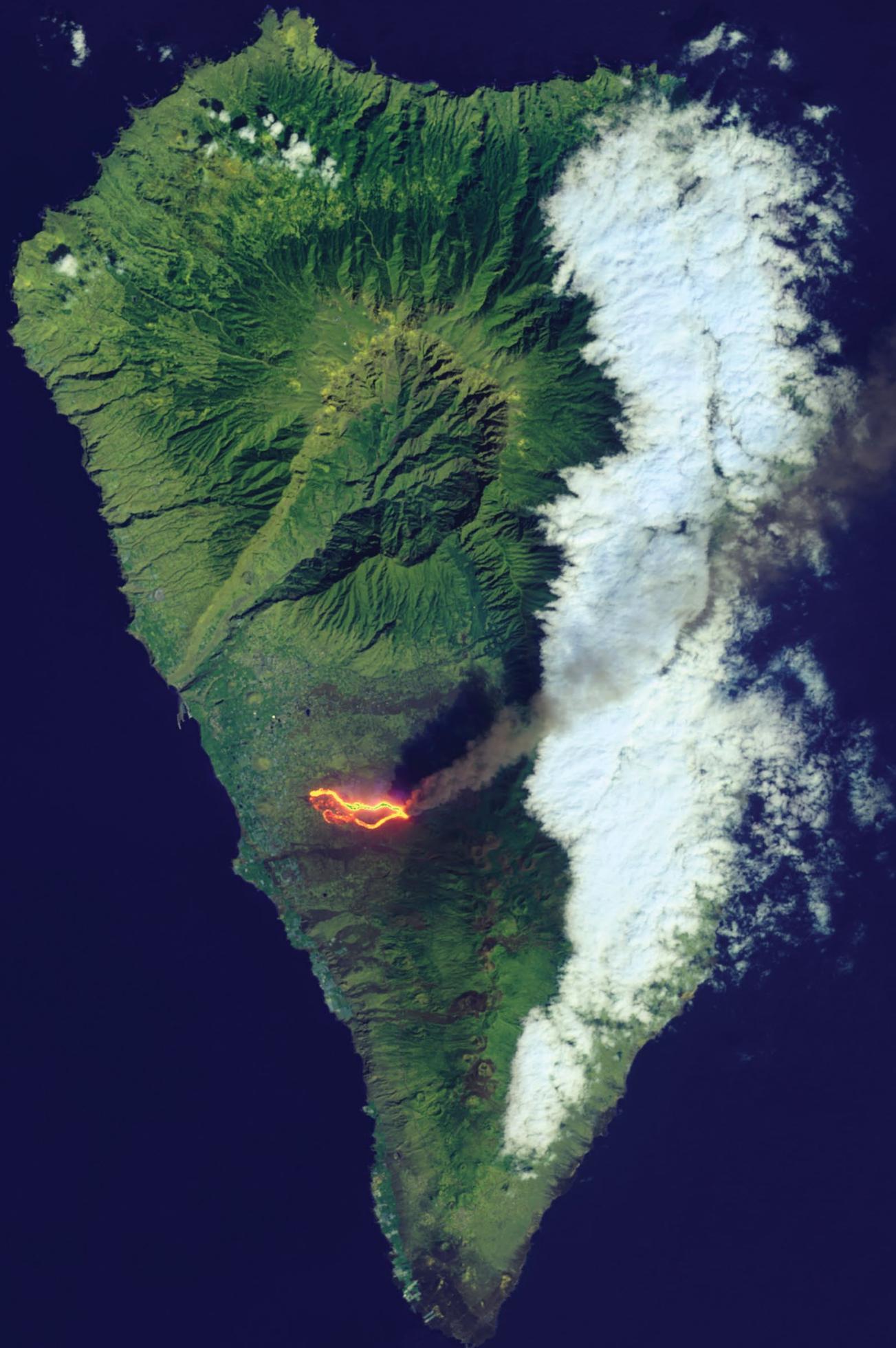


Figure 1 - Terra MODIS image of the ash plume



Figure 2 - Aqua MODIS image of the 'bull's eye' shaped cloud

NASA Earth Observatory images by Lauren Dauphin, using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview.



After Cumbre Vieja split open and began erupting on September 19, 2021, a slow-moving wall of basaltic lava began bulldozing its way through populated parts of La Palma. Lava flows have destroyed hundreds of homes, buried dozens of kilometres of roads, and consumed farmland as molten rock creeps down the western flank of the volcanic island toward the ocean.  
*NASA Earth Observatory image by Lauren Dauphin, using Landsat-8 data from the U.S. Geological Survey.*

# La Palma Volcano: How Satellites help us Monitor Eruptions

*European Space Agency*

Since the Cumbre Vieja volcano began erupting on September 19, 2021, lava has burned through homes, roads and farmlands causing mass destruction on the west part of the Canary Island of La Palma. Cumbre Vieja means 'The Old Summit' in Spanish. Satellite imagery has helped authorities monitor and manage the ongoing crisis. From capturing images of the rivers of lava, to measuring gas emissions and assessing damage, the fleet of Copernicus Sentinel satellites has been providing crucial data for local teams.

On October 9, it was reported that parts of the northern face of the volcano's cone had collapsed, leading the lava to overflow in different directions. On Sunday, October 11, 21 seismic movements were detected, with the largest measuring 3.8 on the Richter scale, according to the *National Geographic Institute of Spain (IGN)*.

A build-up of ash and dust on the runway forced authorities in La Palma to close the island's airport, according to Spain's airport authority AENA. It was the second time the airport had been closed due to ash build-up since the eruption began.

In stunning new images taken on October 10, the new river of lava belching from the Cumbre Vieja volcano was captured by the **Copernicus Sentinel-2 mission**. These Sentinel-2 images have been processed in true colour, using the shortwave infrared channel to highlight the new flow of lava (figure 1).

The *Volcanology Institute of the Canary Islands (Involcan)* stated that the lava flow, with temperatures up to 1240°C, destroyed the few remaining buildings still standing north of the Todoque neighbourhood.

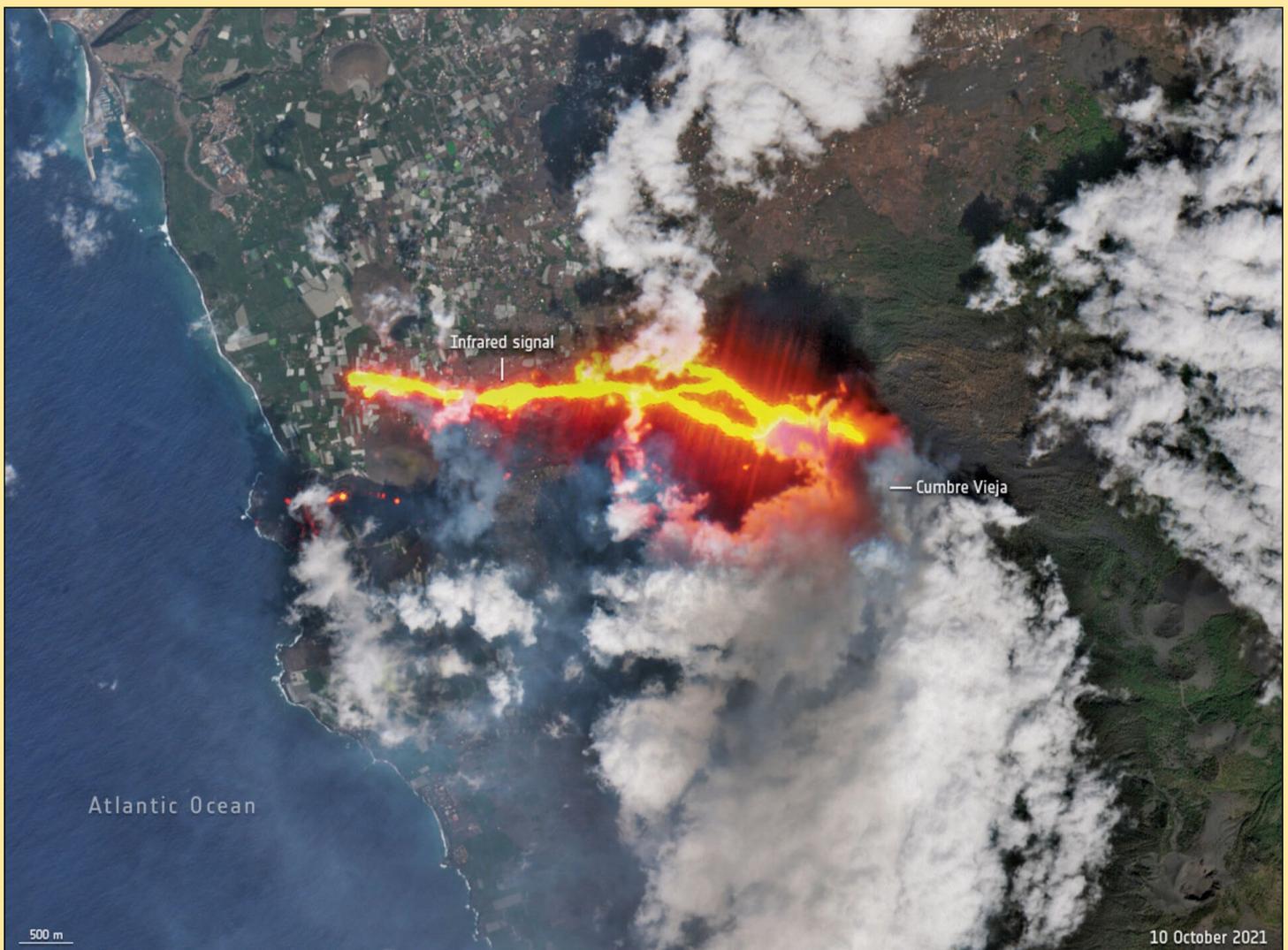


Figure 1 - The New lava river as captured by Copernicus Sentinel-2  
Image © contains modified Copernicus Sentinel data (2021), processed by ESA, CC BY-SA 3.0 IGO

In response to the ongoing eruption, the *Copernicus Emergency Mapping Service* was activated. Since its activation, this service has released 17 mapping products to monitor the lava flow which has affected 497 hectares of land and destroyed over 1100 buildings (as of October 8).

Satellites in orbit carry different instruments that provide a wealth of complementary information to better understand volcanic eruptions. Atmospheric sensors can identify the gases and aerosols released by the eruption, as well as quantify their wider environmental impact.

This image shows the sulphur dioxide emissions from the eruption on 6 October captured by the **Copernicus Sentinel-5P** satellite, moving over the Atlantic Ocean towards Central America. Sentinel-5P can monitor sulphur dioxide, aerosol and ash emitted by volcanic eruptions and follow their movement through the atmosphere.

ESA's Copernicus Sentinel-5P mission manager, Claus Zehner, commented:

*'This volcanic eruption demonstrates how Sentinel data can support different operational Copernicus services. Sentinel-5P sulphur dioxide measurements can be used by the Copernicus Atmospheric Monitoring Service to help aviation companies to avoid volcanic ash and sulphur dioxide plume encounters.'*

*'Sentinel-2 lava flow measurements can support the Copernicus Emergency Management Service in case of natural disasters like a volcanic eruption.'*

Sulphur dioxide concentrations can be monitored using the Copernicus Sentinel-5P Volcanic Sulphur Dioxide online platform. Using data from the Copernicus Sentinel-5P satellite, the platform shows the daily sulphur dioxide concentrations coming primarily from volcanic sources.

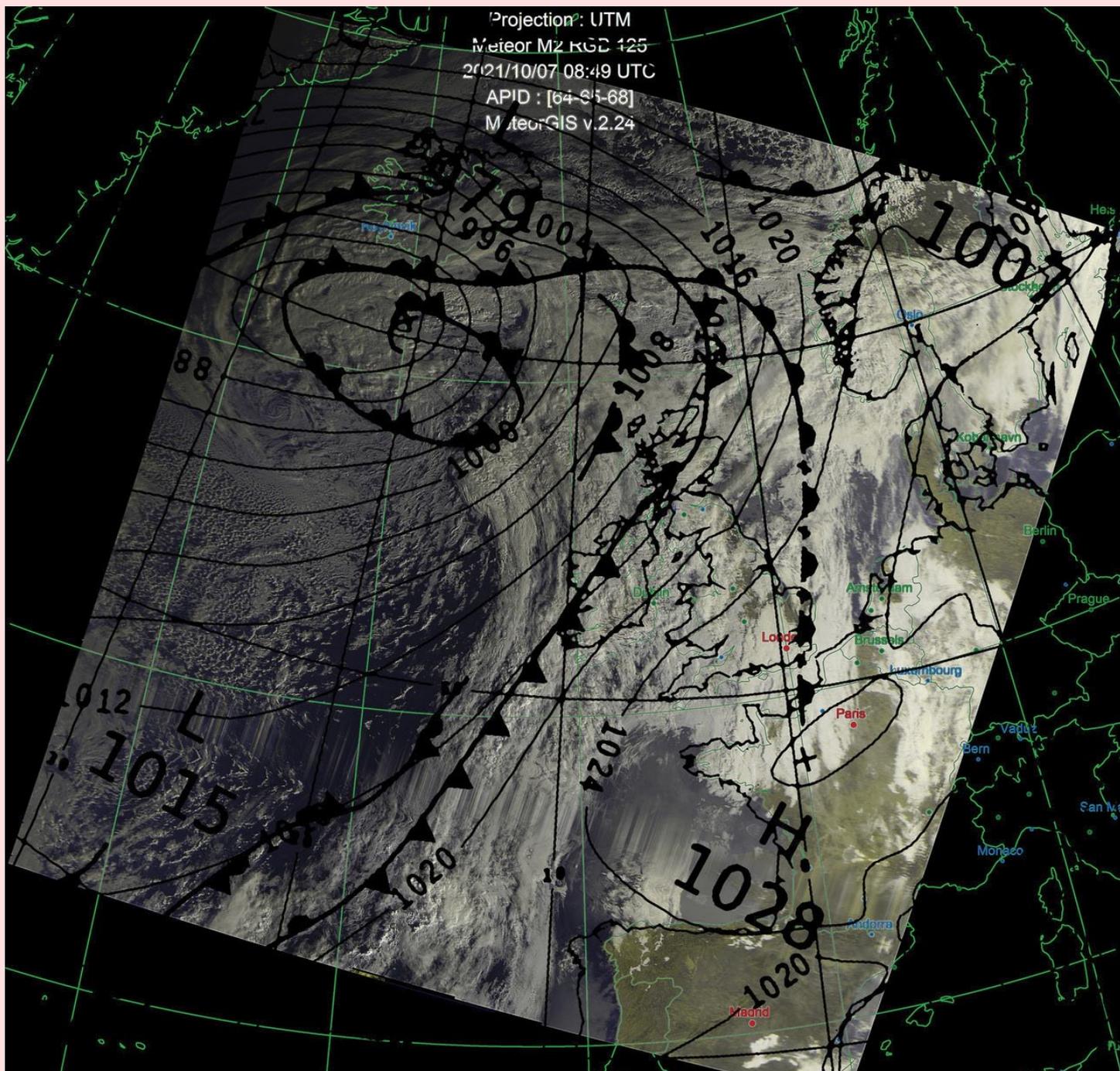


Figure 2 - Sulphur dioxide concentrations on 6 October 2021

Image © contains modified Copernicus Sentinel data (2021), processed by ESA, CC BY-SA 3.0 IGO

# Overlay MetOffice Surface Pressure Charts over Meteor M2 Images

*Richard Fairman*



Receiving and decoding weather images from NOAA and Meteor polar orbiting satellites is a real possibility with the correct antenna, receiver/SDR dongle and software. Currently the main live weather satellites are the USA NOAA 15, 18, 19, and from the Russians Meteor M2. NOAA satellites provide APT with a resolution of 4 km/pixel but the Meteors deliver LRPT which has the higher resolution of 1 km/pixel.

Overlaying surface pressure charts on to weather images brings a new dimension, allowing one to visualise pressure contours and the association of cloud formations

with cold and warm fronts. Up until now the overlaying of surface pressure charts has only been possible with expensive proprietary software.

Now, I have developed a system to do the same using free image manipulation software and a simple workflow taking about ten minutes.

## Prerequisites

- A clear Meteor M2 Image (.PNG or .JPG file).

There is a link to the M2 image used in creating the above composite in the Appendix.

- A monochrome Surface Pressure Chart that closely matches the time and date of the M2 image. (.GIF file). Pressure charts can be downloaded from these web sites as GIF files. (There is a link to the chart used in creating the above image in the Appendix).

Current charts can be downloaded from:

[https://www.metoffice.gov.uk/  
weather/maps-and-charts/surface-pressure](https://www.metoffice.gov.uk/weather/maps-and-charts/surface-pressure)

Historical charts are available from:

<https://www.willandweather.org.uk/mycharts.php>

- Image manipulation software GIMP.

Download Windows or Linux versions of GIMP from

<https://www.gimp.org/downloads/>

## Workflow

- Save a pressure chart, as a .GIF file, close to the date and time of your M2 image.
- Process the pressure chart (in GIMP) to match the size and orientation of the M2 image.
- Process the pressure chart to remove greyscale and convert it to pure B/W.
- Make the pressure chart background transparent and copy to clipboard.
- Resize the M2 image to match the size of the pressure chart.
- Paste the pressure chart as a layer over the M2 image.
- Manipulate the pressure layer so that features such as country outlines align as closely as possible.
- Adjust the opacity of the pressure layer to suit taste.
- Export the pressure chart and M2 images as a single file of type **.PNG**.

Each stage of this workflow is described in detail below.

### Save a MetOffice Pressure Chart as a GIF file

**Note** - the Pressure Chart you save needs to be from as close as possible to the Date and Time that your M2 image was transmitted. Historical charts are available at:

<https://www.willandweather.org.uk/mycharts.php>

- 1 Navigate to the MetOffice web site at

[https://www.metoffice.gov.uk/  
weather/maps-and-charts/surface-pressure](https://www.metoffice.gov.uk/weather/maps-and-charts/surface-pressure)

- 2 Click on **'Black and White'** above the coloured chart
- 2 Right-click on the displayed B/W chart.
- 3 Select **'Save Image as'**.
- 4 Choose a save location and click on **'Save'**.

### Scale the MetOffice Pressure Chart

- 1 Open GIMP.
- 2 Click the **'File'** tab and import your Pressure Chart image by selecting **'Open... (CTRL + O)'**.
- 3 After the image loads, click the **'Image'** tab and select **'Scale Image'** from the drop-down menu.
- 4 A **'Scale dialog'** box will appear to enable edits.

- 5 Adjust the image by width to 6000 pixels.

- 6 Click **'Scale'** to proceed.

### Rotate the MetOffice Pressure Chart

- 1 Click the **'Image'** tab and select **'Transform/Arbitrary Rotation'** from the drop-down menu.
- 2 A **'Rotation'** dialog box will appear to enable edits.
- 3 Rotate the image by entering the **'Angle'** as 37 degrees.
- 4 Click **'Rotate'** to proceed.

### Convert the MetOffice Pressure Chart to pure B/W

- 1 Click the **'Colors'** tab and select **'Threshold'** from the drop-down menu.
- 2 A **'Threshold'** dialog box will appear to enable edits.
- 3 Adjust the image by dragging the small triangle (under the greyscale panel) left or right to achieve a pure B/W image with minimum pixilations.
- 4 Click **'OK'** to proceed.

### Make the MetOffice Pressure Chart Transparent

- 1 Right-click over the displayed MetOffice Pressure Chart and select **'Colors / Color to Alpha'** from the dropdown menu.
- 2 A **'Color to Alpha'** dialog box will appear with white as the selected colour.
- 3 Click **'OK'** and the GIF file will have a transparent background indicated by a chequerboard effect.
- 4 Click **'OK'** to proceed.

### Copy the MetOffice Pressure Chart to the Clipboard

- 1 Click the **'Edit'** tab.
- 2 Select **'Copy'** from the drop-down menu.
- 3 The MetOffice Pressure Chart that has been scaled/rotated/pure B/W and transparent is now on the clipboard ready for pasting atop the M2 image later.

### Scale the Meteor M2 image

- 1 Click the **'File'** tab and import your Meteor M2 image by selecting **'Open... (CTRL + O)'**.
- 2 After the image loads, click the **'Image'** tab and select **'Scale Image'** from the drop-down menu.
- 3 A **'Scale'** dialog box will appear to enable edits.
- 4 Adjust the image by width to 3500 pixels.
- 5 Click **'Scale'** to proceed.

### Paste the MetOffice Pressure Chart over the M2 image

- 1 Click the **'Edit'** tab.
- 2 Select **'Paste as / New layer in Place'** from the drop-down menu.
- 3 Click the **'View'** tab and select **'Zoom-25%'** to display the entire Meteor M2 image on screen.

**Note:** the Met Office Pressure Chart is now overlaying the M2 image as a separate layer but may not yet be in a position to be visible. It will have to be repositioned and aligned.

### **Align the MetOffice Pressure Chart over the M2 image**

- 1 Click on the 'Layer' tab.
- 2 Select 'Transform/ Offset' from the drop-down menu.
- 3 The 'Offset Layer' dialog box appears.
- 4 It is now possible to left-click and drag the MetOffice Pressure Chart layer so that it can be aligned with known features, such as country outlines on the underlying M2 image.
- 5 When you are happy with the alignment click 'OK'.

### **Note**

The angle of the M2 image varies with successive M2 passes, so you may have to adjust the rotation from the 'Layer' tab by using 'Transform/Arbitrary Rotation'.

### **Adjust the Opacity of the Met Office Pressure Chart**

**Note:** the MetOffice Pressure Chart overlaying the M2 image as a layer may obscure some of the underlying M2 image features. The opacity of the layer can be adjusted to correct this by means of the 'Opacity' setting in the lower right of the GIMP window.

### **Export the composite image as a PNG File**

- 1 Click on the 'File' tab.
- 2 Select 'Export' As from the drop-down menu.
- 3 The 'Export Image' dialog box appears.
- 4 Rename the file with a .PNG file extension.
- 5 Select where you would like to save the .PNG file.
- 6 Click on 'Export'.
- 7 The 'Export Image' as PNG appears.
- 8 Click on 'Export'.

### **Note**

**There is a bug in GIMP that can result in a pasted image failing to retain its size. You can correct this by clicking the 'Layer' tab and selecting 'Scale layer' from the menu.**

---

### **Appendix**

The sample **Meteor M2 Image** shown above can be downloaded from this [clickable URL](#)

[https://muglihs.sharing.bublup.com/ui/landing\\_page?item\\_id=001-i-086910fe-9df8-4b8f-942d-d576ee0832fb](https://muglihs.sharing.bublup.com/ui/landing_page?item_id=001-i-086910fe-9df8-4b8f-942d-d576ee0832fb)

The original **Met Office Chart**, illustrated above, can be downloaded from this [clickable URL](#)

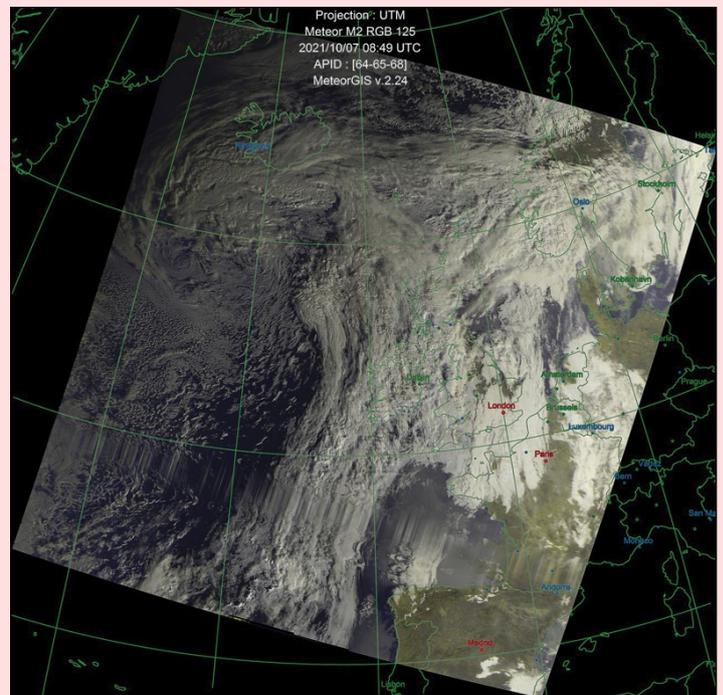
[https://muglihs.sharing.bublup.com/ui/landing\\_page?item\\_id=001-i-5ef65bc8-652a-4619-8bc3-b8677fc90b97](https://muglihs.sharing.bublup.com/ui/landing_page?item_id=001-i-5ef65bc8-652a-4619-8bc3-b8677fc90b97)

This composite image shown at the start of this article can be downloaded from this [clickable URL](#)

[https://muglihs.sharing.bublup.com/ui/landing\\_page?item\\_id=001-i-c8e256a6-15f0-476a-97ed-53ac3fda37d8](https://muglihs.sharing.bublup.com/ui/landing_page?item_id=001-i-c8e256a6-15f0-476a-97ed-53ac3fda37d8)

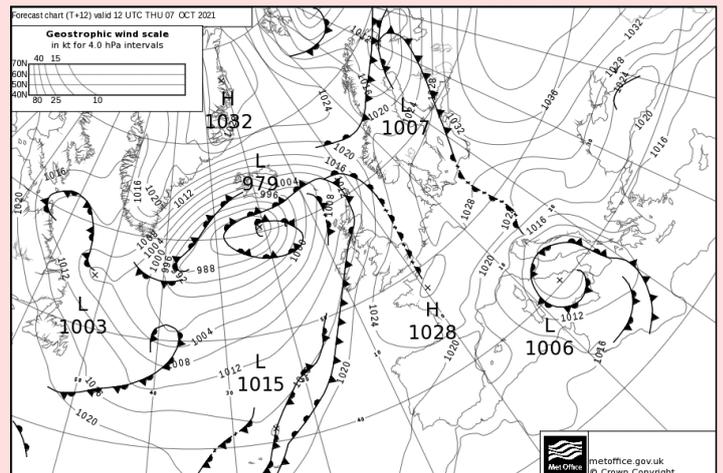
### **Finally**

It's worth mentioning that the scaling and rotation settings described in the text work well for these specific images. You may find that you have to change these slightly for use with your own Meteor M2 images.



This is an illustration of the Meteor M2 image used to create the large composite image at the top of this article.

There is a link to the full sized image below which you can download to try out the technique in GIMP yourself.



This is an illustration of the Met Office Chart that was used to create the overlay on the composite image.

There is a link below where you can download it for use in GIMP.

# Ice Persists in the Northwest Passage

NASA Earth Observatory

Story by Kathryn Hansen

For centuries, explorers have tested the icy waters of the Arctic, looking for sea routes through the cluster of islands north of mainland Canada. Such a route, known as the Northwest Passage, can dramatically shorten the journey between the Pacific and Atlantic Oceans. The decline of sea ice in the Arctic Ocean has made this passage increasingly viable. But as this image shows, it's still not always smooth sailing.

The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's *Aqua* satellite acquired this image shown in figure 1 on August 22, 2021. It shows part of the 'southern route'—one of the two main routes most feasible for the passage of large ships. Since about 2006, the Northwest Passage has become navigable for a short period late in most summers. As of late August this year, that hasn't quite happened.

*'The southern route still has ice,'* said Walt Meier, a sea ice researcher at the *National Snow and Ice Data Center*. *'But it's possible a channel could open up in the next couple of weeks before freeze-up starts in earnest.'*

In this scene, the southern route appears mostly open except for ice that still floats in the straits around Victoria Island and King William Island. Meier notes that these are common places for ice to collect. Sea ice drifts south from the open Arctic Ocean through channels on both sides of Prince of Wales Island; it then hits King William Island, where it piles up.

*'It was this ice that doomed the Franklin Expedition in the 1840s,'* stated Meier. *'They tried to go north of King William, but the ice closed in and crushed their ships. Amundsen, the first to make it through the Northwest Passage in 1903-1906, went south of King William Island, through the*

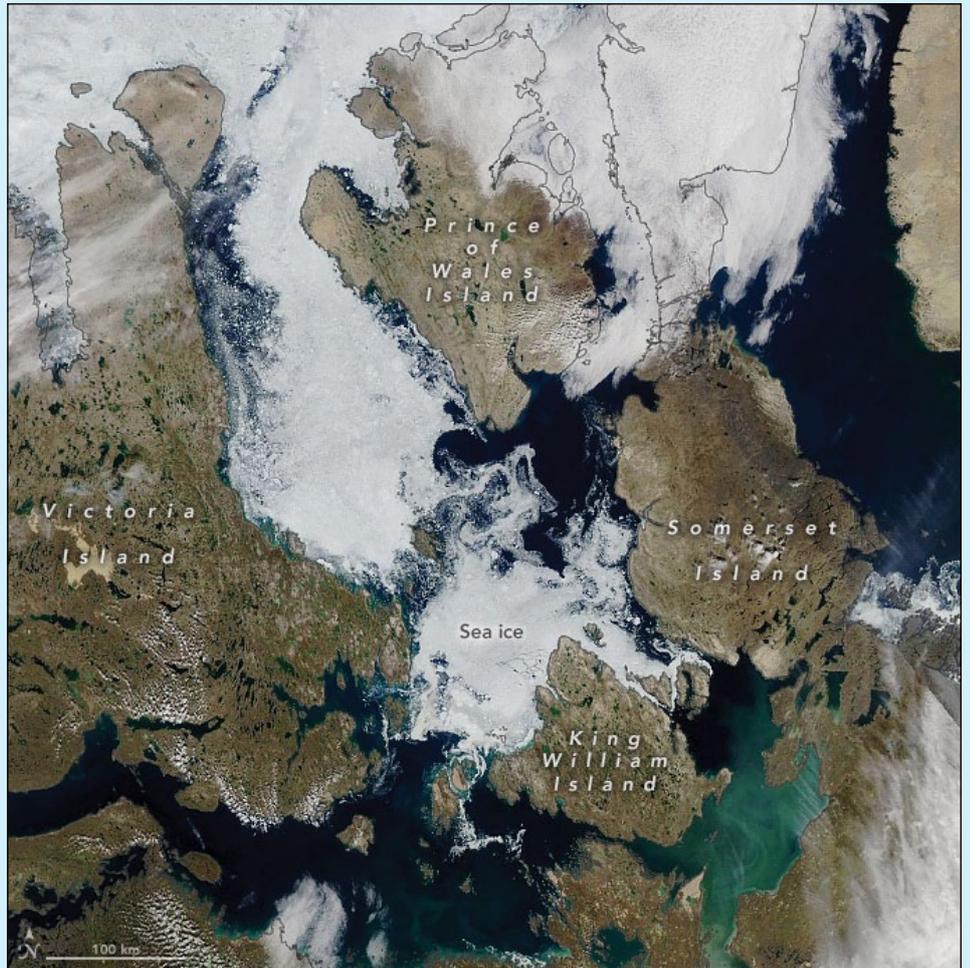


Figure 1 - Part of the southern route through the Northwest Passage  
NASA Earth Observatory image by Lauren Dauphin,  
using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview.

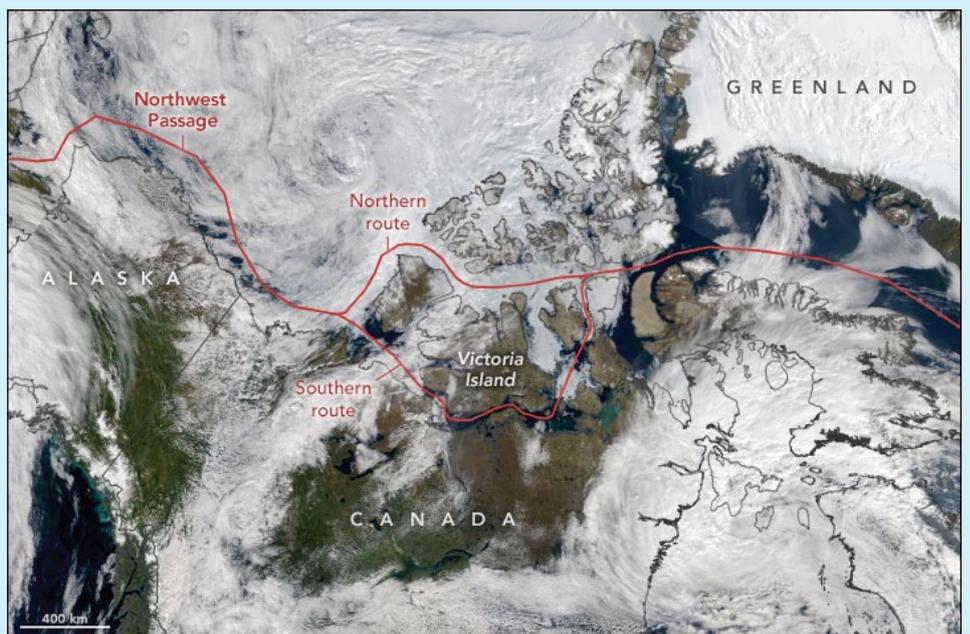


Figure 2 - Both possible routes through the Northwest Passage are highlighted in red.  
NASA Earth Observatory image by Lauren Dauphin,  
using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview.

continued on page 25

continued from page 24

*narrow channel between the island and the mainland. The island protected them from the ice while they wintered over in Gjoa Haven.'*

Today, an increasing number of ships transit the passage, including a large cruise ship that made the journey in 2016. But such voyages are subject to the variable conditions from year to year.

In contrast, the U.S. Coast Guard Cutter Healy—a combined icebreaker and science lab—is equipped to break through sea ice should it encounter any during its transit through the passage this month.

The northern route is locked up with ice this year and probably won't clear before the seasonal re-freeze begins. This route is less sheltered and more susceptible to the influx of ice from the north pushing into the channels. It has opened in the past though, notably, in 2007 and a handful of years thereafter.

Air temperatures also play a role. Meier thinks that average, not-too-warm temperatures in the region during spring and summer may have been a larger factor driving the icy conditions this year. As temperatures continue to increase with global warming, however, the Northwest Passage is likely to be open more often in future summers.

## Saharan Dust Cloud over Europe

### MODIS Web Image of the Day

On July 14, 2021, the Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's **Terra** satellite captured a true-colour image of a vast train of dust moving from Africa into Europe. Dust stretched from Chad and Niger (far south of the lower edge of the image) and over the Mediterranean Sea to reach northern Poland—a distance of about 4,400 kilometres.

Tens of millions of tons of dust blow out from northern and western Africa each year, lofted from the Sahara Desert by strong seasonal winds. Dust storms can degrade air quality, but they also play an important role in absorbing and reflecting solar energy to regulate Earth's climate. Dust also fertilizes ocean and land ecosystems with iron and various minerals that help plants and phytoplankton grow.



Image Credit: MODIS Land Rapid Response Team, NASA GSFC

# LANDSAT: The Satellite That Might Save the Earth

## Part 1 - The Program's History

*Ed Murashie*

After the launch and deployment of the first Earth Resources Technology Satellite (ERTS-1) in 1972, NASA Administrator Dr. James C. Fletcher said "If I had to pick one spacecraft, one Space Age development to save the world, I would pick ERTS and the satellites which I believe will be evolved from it later in this decade." ERTS-1 would later be renamed Landsat-1 and be the first of eight such satellites, including Landsat-9 launched on September 27, 2021.

Part 1 will explain how the program got started, which is almost as colorful as the images they capture, and cover the launch of each satellite. Part 2 will explain each generation's capabilities and give examples of data applications. Part 3 will explain where to get the nearly 50 years of free data and how to manipulate it to tell a story.

### An Unexpected Announcement

To properly set the stage you need to understand what was going on in the United States during the early 1960's when it came to Earth imaging. The launch of the USSR's first satellite Sputnik started a space race which included the launch of the United States meteorological satellites TIROS and Nimbus and the manned missions Mercury and Gemini. TIROS-1 transmitted its first low resolution video camera image on April 1, 1960 and the advanced 3-axis stabilized Nimbus satellite launched on August 28, 1964. John Glenn was the first US astronaut to both orbit the Earth and use a handheld camera in space during his 1962 flight. He used a 35mm Ansco camera he bought at a drug store and two that NASA supplied to take pictures including the first landmass picture 23 minutes into his flight. What is believed to be his very first colour image of Earth from Space, showing north Africa, is reproduced above. It is reputed to be John Glenn's favourite.

NASA had been busy since 1964 working with the Departments of the Interior and Agriculture researching remote sensing using aircrafts including the Convair. The Department of Defense (DOD) had its CORONA classified reconnaissance satellite program throughout the 60's and early 70's which used film return canisters.



The Ansco Autaset camera used by John Glenn to image Earth from orbit in 1962



This color photograph of North Africa from space was taken by John Glenn in the Friendship 7 spacecraft during NASA's Project Mercury MA-6 mission, Feb. 20, 1962

*Credit: John Glenn Archives—The Ohio State University*

Landsat's beginnings can be traced to Dr. William Pecora who was the director of the United States Geological Survey (USGS), the science branch of the Department of the Interior (DOI). Dr. Pecora, after seeing the meteorological satellite and manned spaceflight images, realized a satellite in orbit capable of taking images of sufficient quality would be beneficial for Earth resource studies. He began his campaign to convince Stewart L Udall, the secretary of the Interior, of the idea of a satellite. Dr. Pecora asserted that the cost using a satellite would be "far less than the cost of photographing the Earth by conventional means". Already having explored land resources by conventional means, the USGS entered into a cooperative agreement with NASA to study land and water from space in January 1966.

On September 21, 1966 Secretary Udall announced the Earth Resources Observation Satellite (EROS) program and named Dr. Pecora as the program lead. In a separate statement Dr. Pecora stated "we plan to fly the first satellite in 1969" and "the cost of launching the first EROS vehicles is not expected to exceed \$20 million".

Even though NASA was aware of and consulted on the USGS' interest in satellites, the casual announcement by Secretary Udall came as surprise to most at NASA. They felt they had to respond the same day by issuing their own statement which in part stated "There have been joint studies and discussions of possible satellite programs but specific flight plans and patterns of funding have yet to be worked out. Before a fully worked out program to use operational satellites can be approved a long period of experimental work must take place". The USGS insisted NASA should not have been surprised since they suggested NASA include the development of a small orbiting Earth resources observatory in their 1966 budget. Other NASA folks were interested at the prospect

of developing space-based imaging technology for use on other NASA missions.

The DOD was concerned by the announcement, they felt any unmanned satellite Earth resources survey program could jeopardize their satellite reconnaissance program. A publically known satellite program orbiting over hostile locations and taking images could cause hostile international reactions and bans. A declassified position paper stated "It is a good time to consider the evolution of a Presidential Policy which would direct NASA toward an Earth resources survey program, aircraft oriented, which would be more economical and productive than present ERS program proposals and would not conflict with the National Intelligence Satellite Collection Programs."

### Under New Management

The February 17, 1967 edition of the Missile/Space Daily announced that "the Department of Interior has relinquished management of its EROS program to NASA" and that "there has been a little friction over the program between people at NASA and the EROS officials at the U.S. Geological Survey - largely, it seems, over the timing of the project". The USGS still wanted to launch the first operational satellite in 1969. Insisting there were flight ready systems, they issued their performance specifications to NASA on October 21, 1966. NASA insisted the first missions were research rated and that more research had to go into the sensors and data communications. They issued a statement saying "It is clear that many aspects of the spacecraft dictated by your performance specifications are just at or beyond the current state of the art". NASA pushed forward on their schedule with Goddard Space Flight Center by issuing proposal requests for mission analyses and spacecraft designs. One of the proposals came from TRW Systems Group with its extensive 18 volumes based on the Orbiting Geophysical Observatory satellite only to be shelved in favor of using the Nimbus satellite platform.

1969 was a busy year for the ERTS research and budget approval. The Apollo 9 crew was not only checking out the lunar lander for the first time in Earth orbit, but they also ran multispectral terrain photography experiment S065. The experiment consisted of four Hasselblad 70 mm cameras mounted to the command module's hatch window. False color infrared, green filtered, red filtered, and black and white infrared images were taken in an effort to find the best types of images to use to study the Earth. Meanwhile the public was checking out the Nimbus III model and Earth Resources Technology Satellite concept model at Disneyland featured in the "Benefits from Space" exhibit at the Carousel of Progress. The year ended with the Senate approving NASA's Earth resources survey program budget of 25.1 million split two ways: 11 million for its aircraft program and 14.1 million for two ERTS satellites.

Between the end of 1969 and the middle of 1970 NASA had a contract with its key suppliers. General Electric, the folks that manufactured the Nimbus, would be the prime contractor and supply the spacecraft, data collection, and

handling systems. Radio Corporation of America (RCA), who designed TIROS and its cameras, would supply the three return beam Videocon (RBV) cameras and video tape recorder. Hughes Aircraft Company would supply the multispectral scanner (MSS).

### "Mother of Landsat"

Some people arguably call Dr. William Pecora "the father of Landsat" but without question Virginia T Norwood is "the mother of Landsat". Virginia was a Landsat Instrument



Virginia Norwood  
Photo credit: Gail Ginder

Engineer at Hughes Aircraft Company who led the imager team to design the multispectral scanner. She is a remarkable and inspiring woman whose story is worth reading about. Her list of other accomplishments includes a mathematics degree from Massachusetts Institute of Technology, a patent at age 22 for a weather balloon radar reflector while working at US Army Signal Corps Laboratories, designed

the Surveyor's moon lander transmitter, helped design many other antennas, and headed up the Hughes Aircraft Company Microwave Division. This year at age 94 she was awarded the Lifetime Achievement Award from the American Society for Photogrammetry and Remote Sensing and attended the Landsat-9 launch.

To learn more about this highly talented lady, visit the two URLs below:

<https://landsat.gsfc.nasa.gov/article/virginia-t-norwood-mother-landsat>

<https://www.technologyreview.com/2021/06/29/1025732/the-woman-who-brought-us-the-world/>

### Mass Storage

While NASA and its subcontractors were busy with the hardware designs, the DOI and USGS were busy planning and implementing the EROS Data Center. The data center originally was the data storage, retrieval, reproduction, and dissemination center for ERTS imagery, USGS aerial photography, and NASA aircraft data for the public. Today it is that and more after expanding in 1996. It is a ground station for receiving the telemetry and image data from Landsats and other satellites, receives data from international ground stations, and is an Earth resources research location. The initial study by RCA showed that a small location "in the Midwest" between Fargo, North Dakota and Topeka, Kansas was the best location for reception of ERTS over the continental United States. After lobbying by South Dakota Senator Karl Mundt, President Richard Nixon wrote in a letter dated April 2, 1970, "I share your pleasure that it was possible to designate Sioux Falls as the site for the Data Receiving Center as part of the ERTS-EROS program". Ground breaking on the \$5 million 120,000 square foot facility took place on April 13,

1972 and its dedication was on August 7, 1973. During the construction, GSFC would process the ERTS data until the EROS Data Center was ready. Today the data center holds an estimate of 65 petabytes of data going back to the 1930s and employs over 600 people.

### ERTS-A Launch

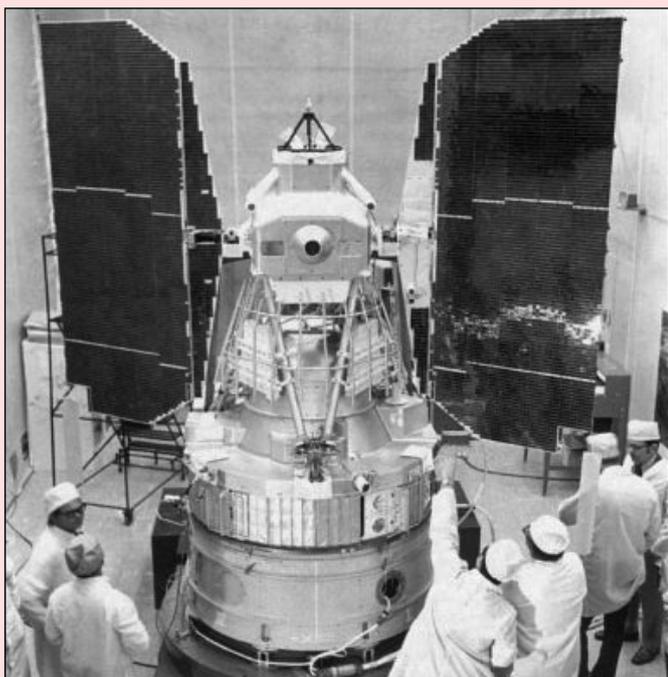
One program milestone occurred during September 22-24, 1970 when GE held the ERTS conceptual design review. Another occurred in March 1971 when NASA locked-in the ERTS designs and final construction was allowed to continue. A major milestone occurred on Sunday July 23, 1972 when ERTS-A successfully launched from Vandenberg Air Force Base (VAFB) in California, but it was not without suspense.



This is the very first MSS image received from Landsat-1, showing a region around the city of Dallas, Texas.

*Image: NASA*

At an ERTS-B prelaunch press briefing on January 14, 1975, NASA Associate Administrator Charles Mathews announced that once in orbit ERTS-B would be renamed Landsat-2 and ERTS-1 would be renamed Landsat-1. NASA thought the name Landsat would complement the name of a planned ocean observing program named Seasat. ERTS-B successfully launched on January 22, 1975 from VAFB, the same location all Landsat launches have occurred, on board an improved two-stage Delta rocket. Operations ceased in 1982 due to a malfunctioning attitude control system and ERTS-B, now Landsat-2, was finally decommissioned on July 27, 1983.



ERTS-1 / Landsat-1  
*Photo NASA / USGS*

A launch delay called on Thursday July 20<sup>th</sup> moved the launch to Saturday July 22<sup>nd</sup> due to a concern regarding the fairing jettison. Another launch delay moved the launch to Sunday July 23<sup>rd</sup> at 10:54 AM due to an erroneous faulty indicator on an auxiliary engine. But finally at 11:06 AM PDT ERTS-A launched on board a two-stage Thor-Delta rocket and became ERTS-1 once in orbit. The first MSS images were received the next day and the first in the Landsat archive received on July 25, 1972 were of Dallas, Texas area.

### Landsat-2 through Landsat-5

The 1970 NASA budget called for two similar ERTS satellites, ERTS-A and ERTS-B. Each was designed to have a one year operational life span and ERTS-B was to launch approximately 15 months after ERTS-A. Even though the RBV imager only operated from July 23, 1972 until August 5, 1972, the rest of ERTS-1 continued to operate well past its one year designed lifetime. It was finally decommissioned on January 6, 1978. ERTS-1's longevity was fortunate because ERTS-B's launch was delayed for a year while NASA studied ERTS-1's results. A Senate committee was not happy with the delay and called NASA to explain it in October 1974.



ERTS-1 / Landsat-1 pictured on its launchpad  
*Photo: NASA*

Defining and budgeting ERTS-C was a struggle between NASA and the Office of Management and Budget (OMB). NASA believed that an ERTS-C research satellite was required because it would be “technically more advanced than ERTS-1 and -B, will be required to demonstrate fully future operational potentials ...” They also believed it needed to be budgeted for 1976 because “a gap between ERTS-B and -C would ‘dead-end’ critical experiments; would tend to dissipate the technical teams”. The Office of Management and Budget believed “that continuity of data is not necessary to carry out an effective assessment of ERTS technology” and that “consideration of ERTS-C should be deferred to next year’s budget (1977) when more information will be available to the Administration”. The final decision was that NASA would absorb the cost of ERTS-C in its 1976 budget and would require \$40 million additional in FY 1977 and FY 1978. ERTS-C would also be the last research satellite before going operational. Negotiations delayed the construction and launch of ERTS-C until March 5, 1978. Once in orbit ERTS-C was renamed Landsat-3. ERTS-C was similar in design to ERTS-A and B and operated until March 31, 1983.

Landsat-D and Landsat-D Prime both used the same spacecraft bus which differed from the one used for ERTS-1, -2, and -3 and were designed with a three year lifetime. They were built by GE Astro Space and used Fairchild’s Multi-mission Modular Spacecraft (MMS) with a Landsat Instrument Module (IM). The RBV video cameras were replaced with a Thematic Mapper (TM) and were the first NASA satellites to use the Global Positioning System (GPS). Landsat-D successfully launched on July 16, 1982 and was renamed Landsat-4. It was plagued with antenna and solar panel problems but managed to operate intermittently until December 14, 1993 when it could no longer transmit data. All previous Landsats were operated by NASA but on January 31, 1983 Landsat-D satellite operations were transferred to the National Oceanic and Atmospheric Administration (NOAA). NOAA had been operating the weather satellites but this would be the first time they also operated Landsat.



Landsat-5  
Image: USGS

Due to the Landsat-D issues, modifications were made to Landsat-D Prime and it was launched earlier than expected on March 1, 1984, and renamed Landsat-5 once in orbit. It had its own problems but still managed to operate until January 6, 2013, which was long enough for it to set a new Guinness World Record for “Longest-operating Earth observation satellite” at 28 years and 10 months.

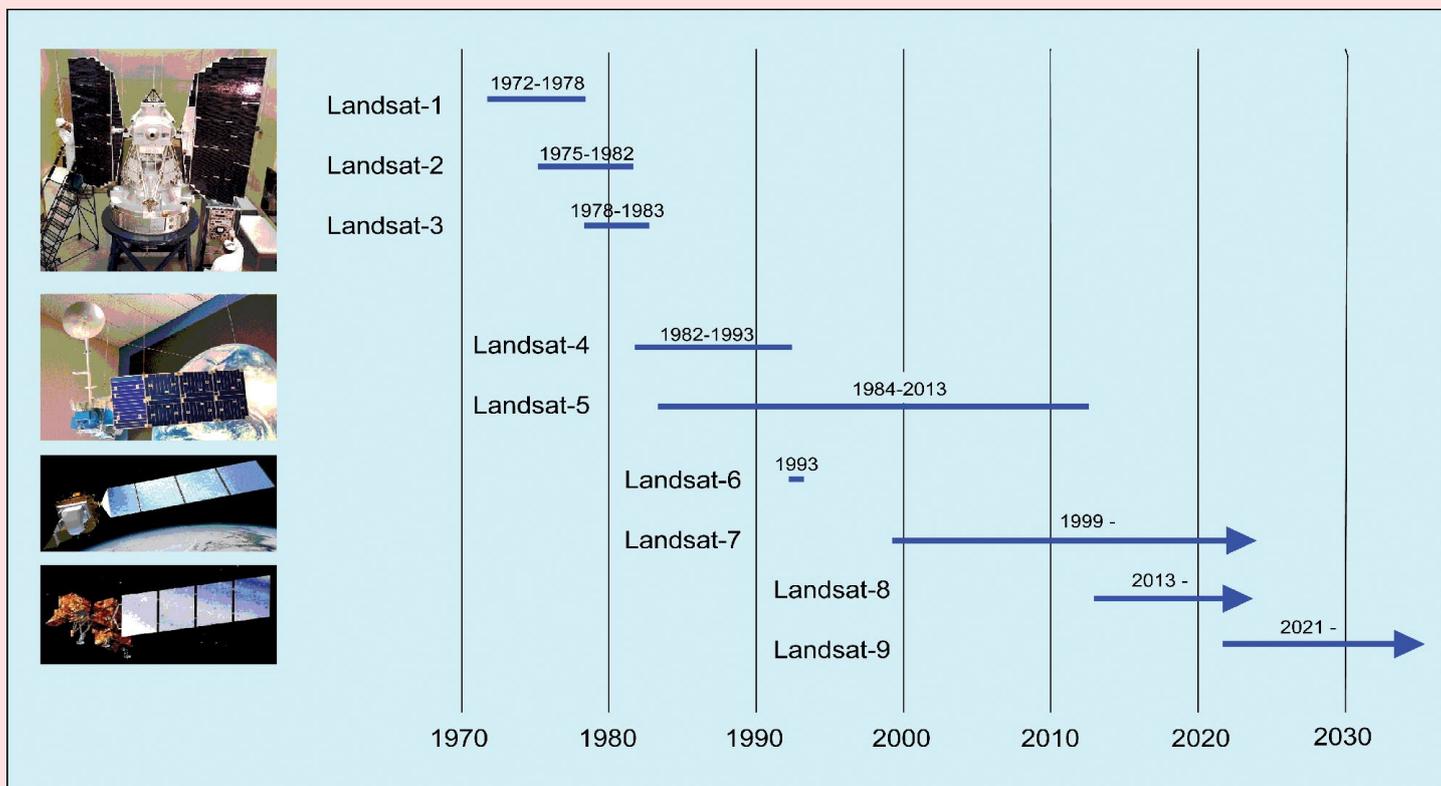
### Commercialization

The Land Remote-Sensing Commercialization Act of 1984 was enacted on July 17, 1984 after the launch of Landsat-5. One of the findings was “competitive, market-driven private sector involvement in land remote sensing is in the national interest of the United States.” Another key finding was “such cooperation should be structured to involve the minimum practicable amount of support and regulation by Federal Government”. One of the outcomes of the act was the Hughes Aircraft Company and RCA partnering in 1985 to form the Earth Observation Satellite Company (EOSAT) who had a ten-year contract to exclusivity rights to market Landsat data and were tasked with building Landsat-6 and -7. Even by 1989 EOSAT was still having problems making a profit and NOAA, who was supplying financial backing, announced they would shut Landsat-4 and -5 due to a lack of money. Congress stepped in and provided emergency funding, which they continue to do every year to the tune of \$500 million. The once promised customer cost of \$2 per Landsat image was now running \$4000 and the number of customers was dwindling.

Congress realized the valuable national asset that Landsat represented, so on October 28, 1992 the Land Remote Sensing Policy Act of 1992 was passed which repealed the 1984 Act. The following key findings can be found in the act: “Recognizing the importance of the Landsat program in helping to meet national and commercial objectives, the President approved ... a National Space Policy Directive which ... commits the United States to ensuring the continuity of Landsat coverage into the 21<sup>st</sup> century. Unenhanced Landsat-7 data should be made available to all users at the cost of fulfilling user requests. Landsat remains an unclassified program that operates according to the principles of open skies and nondiscriminatory access. Development of the remote sensing market and the provision of commercial value-added services based on remote sensing data should remain exclusively



A visualisation of Landsat-9 in orbit  
Image: NASA



Landsat Timeline

the function of the private sector.” The last finding allows companies like Google to use Landsat and other sources of satellite images, like those from Copernicus, in their Google Earth program. EOSAT ceased business at the end of 1992 and now Landsat had the financial backing of the U.S. Government. Landsat-6 could be launched and Landsat-7 could be built.

### Landsat-6 through Landsat-9

The Landsat-6 was manufactured by GE Astro Space and the spacecraft bus was based on RCA’s Advanced TIROS-N spacecraft design which was which was used in the NOAA and DMSP weather satellites. It is worth noting on your scorecard that GE acquired RCA in 1986 to form the GE Astro Space Division.

The entire division was sold to Martin Marietta in 1993 which merged with Lockheed in 1995 to form the Lockheed Martin we know today. Landsat was launched on October 5, 1993 on a Titan II rocket used for the first and last time in the Landsat program. It failed to achieve orbit when the hydrazine manifold ruptured and the spacecraft, after separating from the booster, was not able to achieve orbit and fell back into the Indian Ocean.

Landsat-7 was similar to Landsat-6 and successfully launched on April 15, 1999 on a Delta II rocket. It carried on the Enhanced Thematic Mapper Plus (ETM+) which was an improvement of the ETM carried on the Landsat-6. The Scan Line Corrector (SLC) failed on May 31, 2003, which causes gaps in what is called Landsat 7 ETM+ SLC-off data images. Landsat-7 is still considered operational but will be

removed from service when Landsat-9 becomes operational, well past its five-year design life.

Landsat Data Continuity Mission (LDCM) spacecraft was built by Orbital Sciences Corporation using its LEOSTar-3 satellite bus and also has a design life of five years. The spacecraft has two new sensors, the Operational Land Imager (OLI) and the Thermal InfraRed Sensor (TIRS). LDCM launched on February 11, 2013 on board an Atlas V rocket and renamed Landsat-8 once in orbit. It is still operational.

Landsat-9 is similar to Landsat-8 except it has improved versions of the OLI and TIRS, the OLI-2 and TIRS-2. The satellite was designed and built by Northrop Grumman Space Systems who acquired Orbital ATK in 2018. Orbital ATK was a merger between Orbital Sciences Corporation and Alliant Techsystems in 2014. Landsat-9 launched on September 27, 2021 and is currently going through a 100-day check out before going operational and being handed over to the USGS. The first image was received on October 31, 2021.

More information about the Landsat missions can be found at the following URL

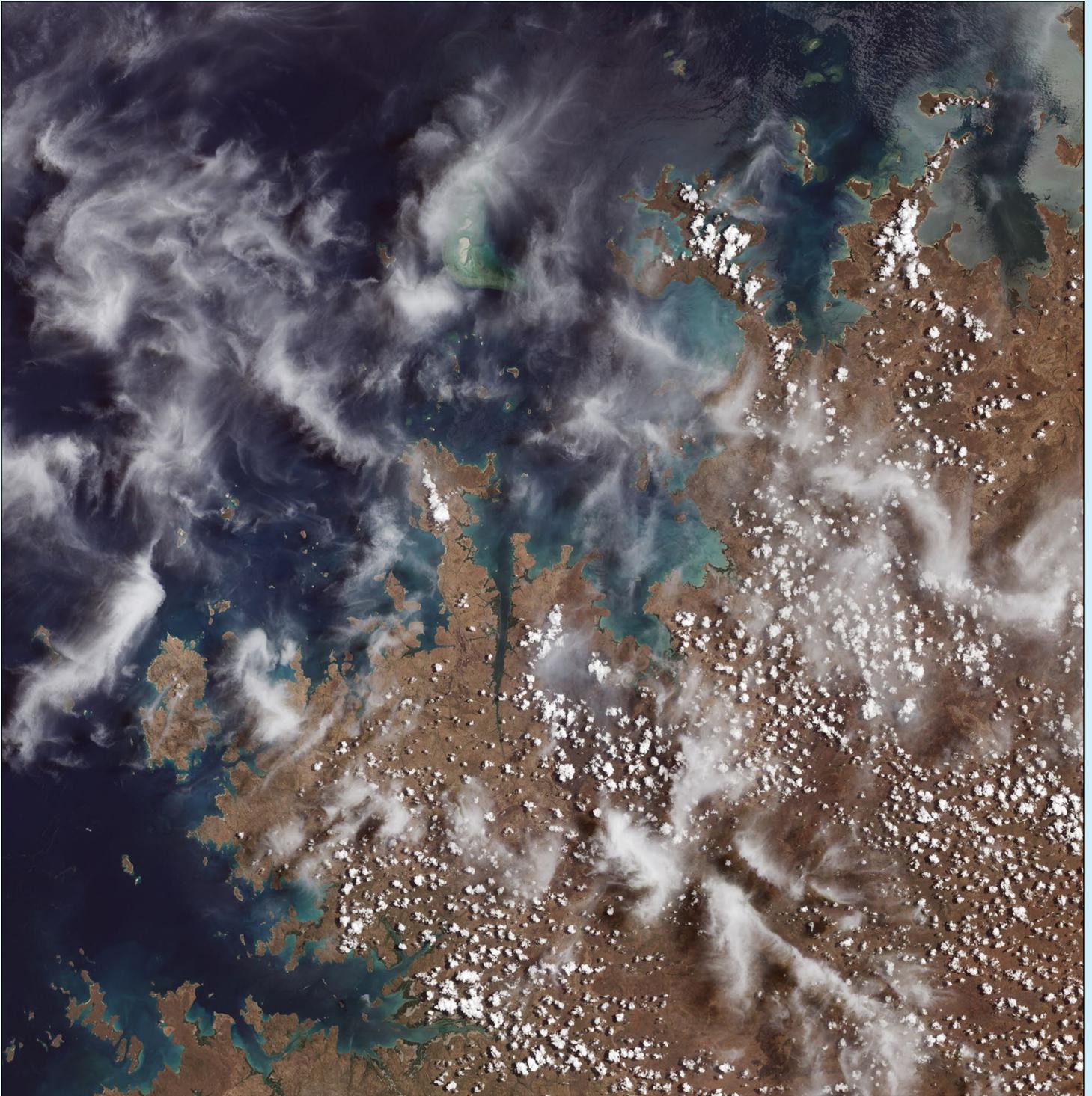
<https://www.usgs.gov/core-science-systems/nli/landsat>

### Next Time

Part 2 will examine the Landsat imagers across the generations which could be helpful if you want to use generational Landsat data. Also covered will be application examples which might help to explain why Landsat might be the satellite that will save the Earth.

# NASA, USGS Release First Landsat-9 Images

NASA



Mangroves are prominent along the northwest coast of Australia. The first image collected by Landsat 9, on October 31, 2021, shows mangroves clustered in protected inlets and bays on the edge of the Indian Ocean. Fluffy cumulus clouds and high-altitude cirrus clouds hover nearby. The aqua colours of the shallow near-shore waters give way to the deep, dark blues of the ocean.

*Credit: NASA*

Landsat 9, a joint mission between NASA and the U.S. Geological Survey (USGS) that launched Sept. 27, 2021, has collected its first light images of Earth. The images, all acquired Oct. 31, are available online at

<https://www.nasa.gov/content/landsat-9-image-gallery>

.These images provide a preview of how the mission will help people manage vital natural resources and understand the impacts of climate change, adding to Landsat's unparalleled data record that spans nearly 50 years of space-based Earth observation.

# Progress update for the Dundee Satellite Station (DSS) Ltd Ground Station November 2021

*Neil Lonie*

Readers of earlier articles will be aware that this initiative follows the closure of the University of Dundee Satellite Receiving Station and our rescuing of the antennas and related equipment which were due to be disposed of. Dundee Satellite Station (DSS) Ltd was formed in order to relocate the station to a new site and operate as a commercial entity.

Since our last update in September 2020, significant progress has been made in establishing the new ground station at the former RAF Errol Airfield, west of Dundee. Our first two tracking antennas were fully serviced, installed and tested by the end of 2020. One of these has been used for routine AVHRR sensor data reception from NOAA and MetOp (L-band) satellites with the most recent images of the UK posted on our website and freely available (Figure 1).

The other antenna was upgraded to a dual X & S band system for satellite Telemetry, Tracking and Command (TT&C) operations of small satellites. It has been used to provide commercial services since early 2021, generating essential revenue to operate the station and move forward with further developments.

Over the course of 2021 the site has more than doubled in area to accommodate additional antennas. Another pair of concrete and structural steel beam bases were constructed, one of which has increased size and mass to allow an antenna of up to five metres diameter should the need arise in future. Our next two tracking antennas have been completely refurbished, serviced and mounted on their new bases with associated cable runs, control and

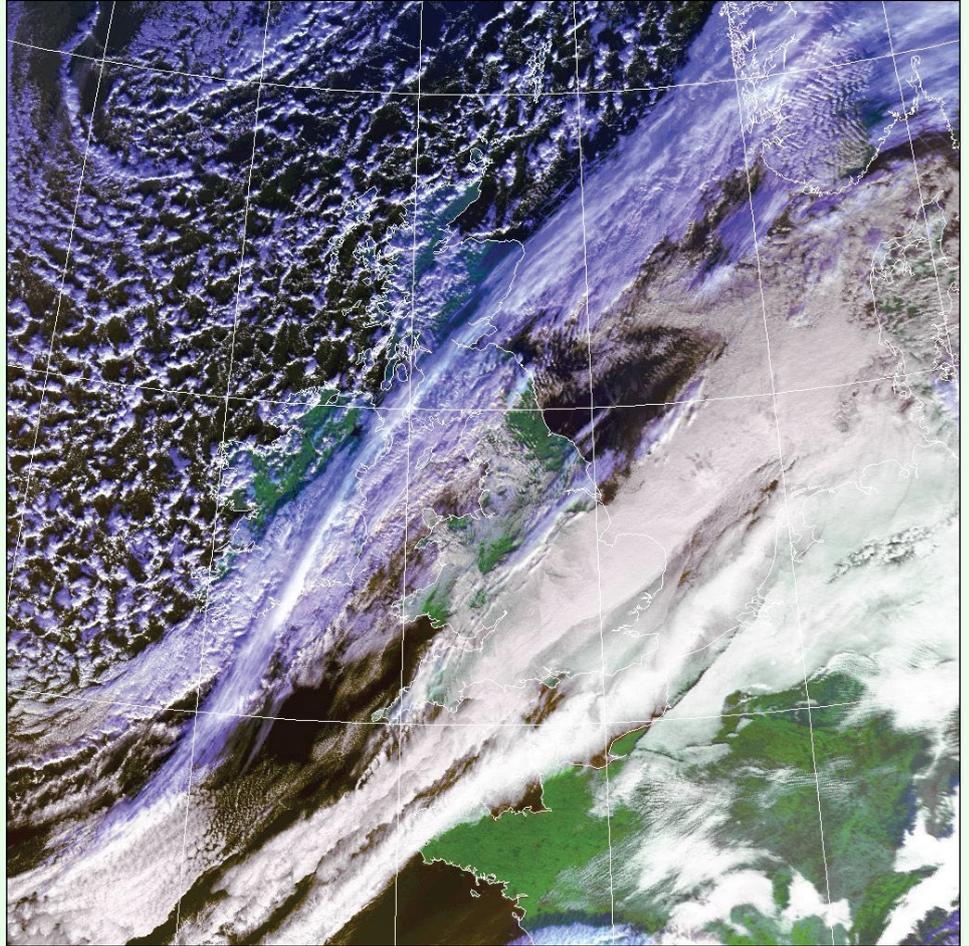


Figure 1 - An example satellite image from the website - AVHRR false-colour image from NOAA-18 on November 24, 2021 at 1120 UTC. See up to date images at:

<https://www.dundeesat.co.uk/>

receiver equipment etc. installed. The first of these antennas has been on test for the past few weeks, routinely acquiring MODIS and VIIRS sensor data from NASA EOS and NPOESS (X-band) satellites.

We anticipate the other antenna being ready for initial testing within the next month but now have all four tracking antennas installed, in-line with our original local authority planning approval (Figure 2). Longer term, the configuration and capability of each antenna will depend on future customer requirements for small satellite support, but the intention is to retain

remote sensing data reception capability for X and L-band polar orbiting satellites and ideally add capability to receive geostationary satellite data.

In order to support more small satellite customers, provide users with EO data as part of regular operations and pursue research collaborations, additional site development work and funding is needed. Key to all of these is provision of direct fibre internet connectivity to the site. Currently we use a wireless connection giving 100 Mb/s upload and download capacity. This was the only option for initial operations and has been adequate so far, but



Figure 2 - The current situation with construction of the ground station, showing all four of the planned tracking antennas now in place. Left to right are the 2.8 m, 2.4 m, 3.7 m and second 2.8 m antennas.



Figure - 3 Civil works to install our fibre cable duct and boxes along a 500 m route around the airfield.

the increased capacity of direct fibre was always essential to expand activities. The process has taken much longer than hoped for various reasons, not least the approximate 500 metre distance to the nearest fibre infrastructure, identifying a suitable connection route with wayleave agreement, and the associated installation costs.

Major inroads on this issue have been made in recent weeks. They include securing Michelin Development business support to assist with installation costs,

enabling us to place an official order through our ISP and confirm the connection route and wayleave. The civil works to install a fibre cable duct across the airfield to the public route are currently ongoing (Figure 3) and we now anticipate our fibre connection will be installed and 'live' by the end of 2021.

In terms of EO data service provision, there are other aspects to address such as establishing data processing and archiving facilities, plus a website that allows user access to resulting

products. We will investigate options to support this in-house, or possibly through partner agreements. However, as soon as our fibre connectivity is 'live' we will have the data distribution capacity to support users that require access to our 'raw' EO data in near real-time and who have their own data processing facilities.

On behalf of DSS Ltd I would like to express our thanks again to the members of GEO for their continued support and interest in the new ground station.

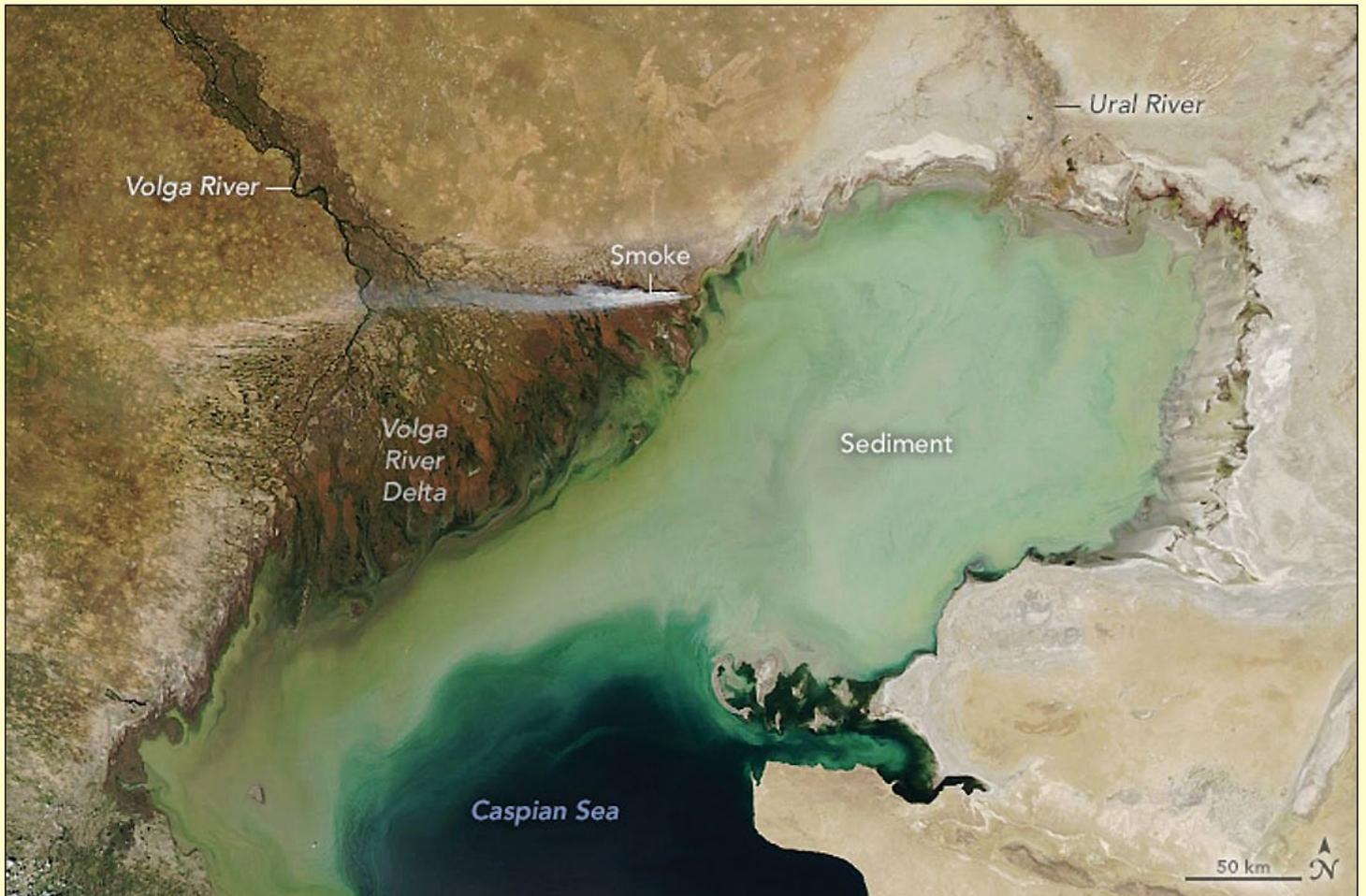
Any reader minded to support the Dundee Satellite Station can do so through their GoFundMe page (Ed.)

<https://www.gofundme.com/f/dundee-satellite-receiving-station>

# The Caspian's Shallow North

NASA Earth Observatory

Story by Adam Voiland



NASA Earth Observatory image by Lauren Dauphin, using MODIS data from NASA EOSDIS LANCE and GIBS/Worldview.

In many parts of the world, sea levels are rising due to global warming. But scientists note that warming and increased evaporation are likely to play out differently for inland seas and lakes.

In the case of the Caspian Sea (technically a lake), scientists anticipate rapid declines in water levels in the coming decades and centuries. Radar altimetry data collected by multiple satellites and compiled by NASA's *Global Water Monitor* indicate that the Caspian's water levels have already been dropping since the mid-1990s.

By one estimate, Caspian water levels could drop by as much as 18 metres by the end of the 21<sup>st</sup> century, enough that it would lose about a quarter of its area and uncover about 93,000 square kilometres of dry land. That's an area about as large as Portugal.

Much of this new land would come from the northern Caspian, a shallow zone that holds just one percent of the lake's volume and has an average depth of between 5 and 6 metres. For comparison, the deepest parts of the lake stretch down more

than 1,000 metres below sea level. The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite acquired this natural-colour image of the northern Caspian on July 17, 2021. Suspended sediment delivered by the inflowing Volga and Ural rivers had discoloured the waters in the northern part of the lake, while winds may also have stirred up sediment.

Losing the northern part of the Caspian could have major ecological consequences. Its shallow waters teem with molluscs, crustaceans, fish, and birds, and seals raise their pups on winter ice that usually only forms in this part of the lake.

*"Current protected areas in the Caspian Sea, most of which cover coastal ecosystems including highly coveted wetlands such as the Volga Delta and other Ramsar sites (wetlands of international importance named after the Caspian coastal city of Ramsar, Iran) will be transformed beyond recognition,"*

wrote a group of European scientists in *Communications Earth & Environment*.



ESA's *Copernicus Sentinel-2* mission captured this magnificent image of the cloud free Shetland Islands on July 1, 2021 with a turquoise-coloured bloom visible to their east. This is assumed to be a bloom of coccolithophores – a type of microscopic marine alga that inhabits the upper layer of the sea.

*Image contains modified Copernicus Sentinel data (2021),  
processed by ESA, CC BY-SA 3.0 IGO*

# Springtime on New Zealand's South Island

*MODIS Web Image of the Day*



Credit: MODIS Land Rapid Response Team, NASA GSFC

Snow caps the spine of New Zealand's Southern Alps as sun shines on the springtime flush of green vegetation in late October 2021. The Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Terra satellite acquired this true-colour image on October 22.

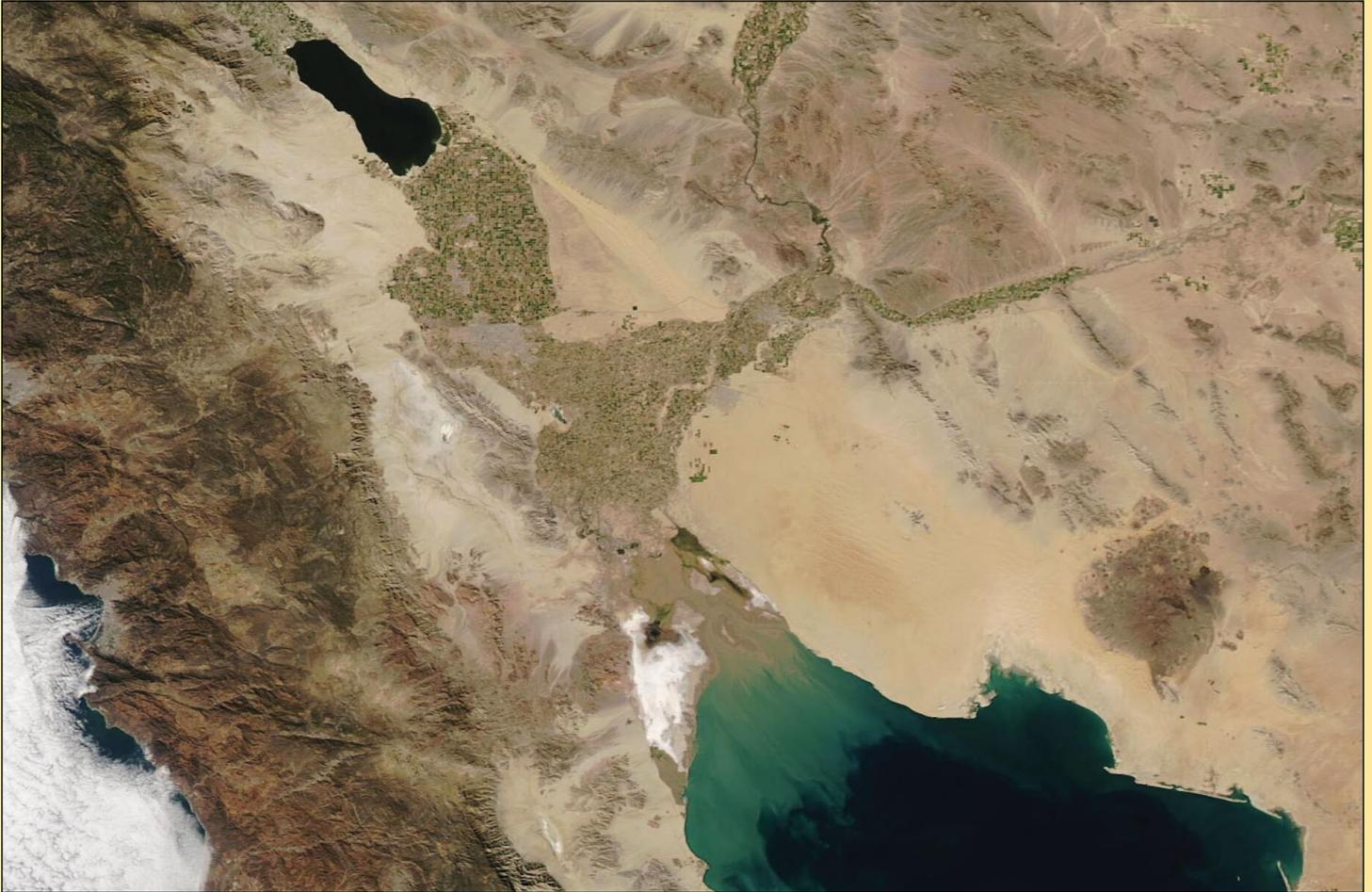
The intense colours—ranging from deep brown to bright green to stark white—give New Zealand's South Island its intense beauty. The tall peaks of the Southern Alps retain snow year-round and divide the country into the extremely moist western shores and the dryer land east of

the mountains. The highest peak in New Zealand is Aoraki/Mount Cook, which rises to 3,754 metres.

Bright colours tint the waters of the Tasman Sea off the western coast. These jewel-tones are the result of a bloom of small plant-like organisms known as phytoplankton. Present in these waters year-round in small numbers, when temperature, hours of sunshine and nutrient availability are just right, the organisms reproduce explosively creating huge blooms that can easily be seen from space.

# Colorado River Delta

*MODIS Web Image of the Day*



*Image Credit: MODIS Land Rapid Response Team, NASA GSFC.*

The grand Colorado River once flowed freely from its source in the central Rocky Mountains in Colorado through about 2,330 kilometres of arid, spectacular scenery across five states before spilling into the northern Gulf of California. Over time, however, the river's water has proven so essential to human life and livelihoods that it has been siphoned off for crop irrigation and for residential use. Only about 10% of all water that flows into the Colorado River actually makes it into Mexico. Once in Mexico, most of those remnants are also used for agriculture or drinking water.

The harnessing of the Colorado transformed the Colorado River Delta. Once filled with lush marshland and many braided channels, the Delta now has diminished into sandy mud flats and scattered areas of marshland. The former rich wetland and riparian ecosystem contrasted strongly against the arid desert and served as an oasis, supporting cottonwood and willow and creating breeding grounds for a large number of native species. With the loss of the Colorado's water, invasive species moved in while the population of native ones dropped steeply.

A joint effort between Mexico and the United States brings some hope to save some of the remaining critical

ecosystems once found so richly throughout the Colorado River Delta. The *Colorado River Binational Agreement* permitted a pulse flow of water from Morelos Dam in 2014 that brought water once again to the Delta. Even this brief flow helped encourage growth of trees and increased nesting bird populations. The current agreement brought a flow of water measuring 35,000 acre-feet (11.4 billion gallons) through the river to reach the Delta between May 1 and October 11, 2021. This annual life-enhancing baptism, which will occur until 2026, is expected to help restore parts of the Delta and support habitat for threatened species.

On November 4, 2021, the Moderate Resolution Imaging Spectroradiometer (MODIS) on board NASA's Aqua satellite acquired this true-colour image of the Colorado River Delta from the Salton Sea to the Gulf of California. Patchworks of green appear at every location where water flows through the river or where water can be diverted to support agriculture. The orange-tinted sands of the Sonoran Desert can be seen in the east while bright white salt flats sit on the western banks of the Delta. A few areas of dark blue along the Delta are most likely pools created by the flow emitted during the summer and early fall of this year.

# Visualising EUMETCast SAF products

*Richard Osborne*

One feature of the EUMETCast product stream that doesn't seem to attract much attention from the amateur user group is the output from the *Satellite Application Facilities* (SAF) network. EUMETSAT supports eight different SAF centres, each concentrating on a different aspect of meteorological data that are derived from Geostationary and Low Earth Orbiting (LEO) satellites. Selected data from seven of them is available on EUMETCast.

As an experiment, I decided that I would try and visualise as many of the SAF products as possible on a Windows based system, so I embarked on a personal research and development programme. Of course, images derived from the SAF products are freely available on the internet but this is not the point. I wanted to do this as an exercise in 'self-training' and to better understand the products.

I need to state that I am not a software or meteorological expert, and that the article should not be interpreted as an authoritative tutorial or 'how to' guide. It merely describes my own efforts, interpretations and understanding (possibly incorrect and misguided) in the hope that some readers may find the material of interest.

## First Steps

I started by exploring the websites of the individual SAF providers, looking for documentation and recommendations (if any) for software applications that could be used to visualise their products. I discovered that the training websites provided by EUMETSAT and EUMeTrain were a particularly rich source of relevant information. After a short time, it became clear that each SAF provider had their own particular method of encapsulating data for transmission over the EUMETCast network, and there would be no 'one size fits all' solution for visualising the data. Each one would need a different approach.

EUMETCast carries data from seven SAF providers. After a quick analysis, I decided not to pursue the *Climate Monitoring SAF* as it only provided a very small amount of data over EUMETCast: nor the *Radio Occultation Meteorology*, as this did not provide Earth referenced images as such. I then examined the remaining five in more detail and the general characteristics are given in Table 1.

SAF Provider	Abbreviation	Theme	Data Format(s)
Ocean & Sea Ice	OSI	Ocean temperatures, sea ice, global winds	netCDF
Land Surface Analysis	LSA	Solar Radiation effects, vegetation, Evapotranspiration, wildfires	HDF5
Hydrology	H SAF	Precipitation, soil moisture, snow	BUFR, GRIB, HDF5, netCDF
Nowcasting	NWC	Cloud properties	netCDF
Atmospheric Composition	AC	Atmospheric Trace gases	HDF5, BUFR

Table 1: General SAF Characteristics

As far as I am aware, every product available from the SAF providers listed in Table 1 can be viewed as a two dimensional image which contains a representation of a specific property such as temperature, wind, ice etc. In addition, the location of the image with reference to the earth is also available which allows for the addition of a basemap to provide coastlines and other geo-referenced features.

I established that four different data formats are used across the SAF providers with the predominant data format being netCDF. This also appears to be the format of choice for new and future products. Indeed, GOES ABI images are already supplied in netCDF format as will those of Meteosat Third Generation.

All these formats have the property of being "self-describing" in common. In simple terms, the data is split into two parts - the operational data itself and metadata which describes how the operational data is organised and can be interpreted. Within the rules of each format, a provider can structure the data in whatever manner they please, making the decoding and visualisation of the data a potentially difficult task. In addition, BUFR and GRIB formats are table driven and rely on the local availability of relevant tables that are generated by the World Meteorological Organisation.

## Software Applications

**Note:** My observations and descriptions of the various software applications relate solely to their use with SAF products provided by the EUMETCast network. The majority of these applications can also be used with other data sources and compatible EUMETCast products.

My next task was to seek out candidate software applications for visualising the data formats described in Table 1. As a non-programmer, I looked for easy solutions based on 'point and click' applications first, starting with *SatSignal* products which I knew and following on with suggestions from the SAF providers themselves. I then searched further afield within the meteorological community, looking for potential software solutions with a relevance to the SAF products.

My searches revealed a number of possibilities and a summary of my findings is shown in Table 2 below. The Category heading is my own derivation which I shall describe in more detail shortly. In general, the most ‘user friendly’ applications are at the top of the table and the most powerful at the bottom.

Please note that the intention of this article is to comment on the suitability of each application for visualising the SAF products and I will not be providing instruction for their use. However, I will identify particular obstacles that I encountered.

### EUMETCast Ready

This category is so named because I understand that these applications were intended to handle EUMETCast data ‘out of the box’: in other words, once installed, a few mouse clicks were all that were required to provide usable images. I had used these applications in the past so I was already aware of their general capabilities but had not evaluated them over the full range of SAF products. Significantly, none of the applications in this category could handle the netCDF data format, so it was clear that other solutions were needed for this.

### BUFRdisplay ([www.elnath.org.uk](http://www.elnath.org.uk))

For visualising BUFR products, Francis Breame’s excellent BUFRdisplay is the “goto” application. It worked for all the SAF products that I tried. There is always the danger that BUFRdisplay does not have the relevant tables installed but I didn’t encounter this potential problem. Coastlines/ country boundaries are displayed and it can open compressed files.

### GRIB Viewer (<http://www.satsignal.eu/software/grib-viewer.htm>)

The GRIB Viewer from David Taylor worked well for the SAF products that I tried except one. Once I had tried using generic tools to visualise the GRIB data, I appreciated that the GRIB Viewer did a lot of work in the background to provide an image that was easy to interpret and also easy to save in a 3712 x 3712 pixel format that matched the MSG optical image resolution. Coastlines/ country boundaries are displayed and it can open compressed files.

### HDF Viewer (<http://www.satsignal.eu/software/hdf-viewer.htm>)

Although the title of the application suggests that it is a generic HDF viewer, it only worked with the LSA SAF. Even then, it would only visualise a subset of the LSA SAF product range. I believe that the reason for this is historical and I will expand on this in a following section covering the LSA SAF. Coastlines/country boundaries are displayed although I found some products (e.g. albedo) where they were not properly aligned for some reason. It can open compressed files.

### Generic

My generic category covers freely available software applications (viewers) that are capable of visualising at least one of the SAF data formats and can handle a range of products that is not restricted to EUMETCast. As a result, the viewers allow for a considerable degree of customisation which requires effort from the user to produce an image that brings out wanted features. Although this article is about usage of these viewers on a Windows system, they all work equally well (if not faster) under Linux because they are all Java based.

To produce a two dimensional image from a SAF product file, the generic viewers need to be provided with observational data that has a two dimensional structure where the location of each and every pixel on a flat canvas is represented by an X and Y co-ordinate. In addition, the viewers need to recognise this data structure otherwise they will not attempt to build the image.

If the X and Y co-ordinates include longitude and latitude, the image can be located on, and combined with, a basemap containing coastlines and other optional features—assuming that the application has this capability. This representation constitutes a *Geographic Co-ordinate System* and it tells the application where each pixel is located on the basemap. An alternative method of locating each pixel is called a *Projection Co-ordinate System* which tells the application how to calculate the position of each pixel based on a definition of the projection to use and a set of values for use in the calculation.

In the following sub-sections, I will describe my experience with each of the generic viewers.

Category	Software Application Name	Data Format Capability
EUMETCast Ready	BUFRdisplay	BUFR
	GRIB Viewer	GRIB
	HDF Viewer	HDF5
Generic	Panoply	netCDF, HDF, GRIB
	McIDAS-V	netCDF, GRIB
	Weather and Climate Toolkit (WCT)	netCDF, HDF, GRIB
	ESA SNAP	netCDF, HDF
	HDFView	HDF5, netCDF
Scientific Analysis and Presentation	MATLAB	netCDF, HDF, GRIB
	R	netCDF, HDF, GRIB
	Generic Mapping Tools (GMT)	netCDF
Geographic Information Systems (GIS)	QGIS	netCDF, HDF
	ILWIS386 + GEONETCast toolbox	netCDF, HDF, GRIB, BUFR?
General Purpose Software	Python, C (examples)	netCDF, HDF, GRIB, BUFR

Table 2: Candidate Software for Visualising SAF Products

## Panoply

(<https://www.giss.nasa.gov/tools/panoply>)

Panoply is provided by NASA and is the most cited viewer as mentioned by the various SAF websites and training modules, and is also my own viewer of choice. I have found it to be the most robust in the sense that it can successfully open and provide basic information including metadata for almost all the SAF files, even if it is unable to form an image. It can also work directly with the compressed files provided by EUMETCast without the need for prior decompression.

When Panoply opens a file, it analyses the dimensional structure of all the variables and provides a data tree where each variable has dimensional property allocated to it. For plottable variables, this can be one of three types.

- Geo2D - The variable has full geo-location information and can be displayed on a basemap.
- 2D - The variable does not have recognisable geo-location information but can be displayed as a two dimensional image.
- 1D - The variable can only be displayed as a graph (line plot)

The downsides with Panoply, from my perspective, are the lack of documentation and also the lack of a command line interface or scripting functions. However, it does allow one set of preferences to be stored, such as map projection and colour table, and these are implemented when the application starts. I discovered that the preferences are held in an XML file so it may be possible to prepare multiple versions of this file and swap them in and out as required but I have not tried this approach to date.

## McIDAS-V

(<https://www.ssec.wisc.edu/mcidas/software/v/>)

McIDAS-V is a comprehensive viewer for satellite imagery and derived products and is provided by the University of Wisconsin-Madison. It can also analyse and manipulate data with mathematical functions although I have not used this capability. It cannot open compressed files.

It has comprehensive documentation, a command line interface and a scripting capability using *Jython* (this is the same as Python but running on a Java engine). It can also display images on a three dimensional globe that can be rotated under user control. However, I did not find the interface to be intuitive, partly because of the large range of functions available. One feature that appears to be unique to McIDAS-V is the ability to view multiple files on a single canvas, effectively merging individual images together to form a larger picture. (Panoply allows only two files to be combined).

Provided McIDAS-V recognises a SAF file as having full geo-location information, it is a competent viewer, although I think that it is poor at handling a simple two dimensional image and would not recommend it for this purpose.

## Weather and Climate Toolkit

(<https://www.ncdc.noaa.gov/wct/>)

I have only included the Weather and Climate Toolkit (WCT) from NOAA because I was aware of the viewer. It

has a heavy emphasis towards US products. Unless I have missed something obvious, it will only display files which contain full geo-location information that it can recognise. In addition, the only map projection that it supports appears to be Plate Carrée, limiting its use for viewing polar regions. However, its use may be of interest outside the SAF product area.

## ESA SNAP

(<https://step.esa.int/main/download/snap-download/>)

The *Sentinel Application Platform* (SNAP) is provided by the European Space Agency, and although it is primarily aimed at the Sentinel series of satellites, it can also process netCDF and HDF files from a wide variety of other sources. I found it to be a complex application that required a considerable amount of work and understanding to produce relevant images and I think that it is aimed at the professional user who requires good analytical tools. I do not use it on a regular basis.

In contrast to the three previously described applications (Panoply, McIDAS-V and WCT), SNAP does not have any built-in basemaps as far as I know and I needed to load a shapefile to add coastline data to an image. As with the other viewers, the coastline data is only shown with files that SNAP recognises as containing full geo-location information using the *Geographic Co-ordinate System*. SNAP does not appear to recognise geo-location in files using the *Projection Co-ordinate System* unless I have missed something.

## HDFView

(<https://www.hdfgroup.org/downloads/hdfview/>)

HDFView is an elegantly simple tool provided by the HDF Group for viewing HDF files. It can also be used as a viewer for netCDF4 files (applies to SAF netCDF products as far as I can tell) as the dataset inside this file type is stored using the HDF5 hierarchical format.

Variables are selected from a data tree and can be viewed as a spreadsheet or as a flat two dimensional image with a limited range of colour palettes. There is no basemap facility.

## Scientific Analysis and Presentation

I have included MATLAB, R and GMT in this category as they are mentioned in training material produced by a couple of SAF providers as a method of producing images. I suspect that one or more of these applications has been used to generate images that are available on some of the SAF websites but they all need suitable scripts for operation. I have no personal experience of these applications and regard them as best suited for professional use.

## Geographic Information Systems (GIS)

I find the term GIS a bit woolly but it seems to encompass creating, managing, analysing and mapping geospatial data and this includes images with geo-referencing properties.

## QGIS

(<https://qgis.org/en/site/index.html>)

QGIS is probably one of the best known free and open-source GIS applications and I did perform a few experiments with it. I was able to import and display a number of SAF related netCDF and HDF5 files but the sheer complexity of the application means that I did not use it as a day to day SAF viewer.

## ILWIS 386

<https://www.itc.nl/about-itc/organization/scientific-departments/water-resources/software-tools-models/ilwis3-and-toolbox-plugins/>

ILWIS 386 is another fully-featured free GIS application (Windows only) from the University of Twente and one which I would not normally pursue. However, a feature that is of particular interest is a plug-in called *GEONETCast Toolbox*.

GEONETCast is a global meteorological dissemination service that includes data from EUMETCast in its broadcast streams. The toolbox is able to ingest files exactly as received by a EUMETCast Tellicast client and convert them into the proprietary ILWIS image format, adding geo-referencing along the way if required. Some SAF products are included in the toolbox catalogue and I believe that it is possible for non-programmers to add additional products if they are missing. For one SAF product, which I shall cover later in this article, the toolbox was the only application that could provide the image that I sought.

The ILWIS 386 core application and Toolbox plug-in come with comprehensive documentation indicating that they can be used for a wide range of image processing functions with EUMETCast products in general but I have yet to experiment with these.

## General Purpose Software

The use of general purpose software can obviously provide any solution but it relies on having a suitable script. In the Earth Observation field, *Python* now appears to be the language of choice, especially as pre-existing software libraries for manipulating netCDF, HDF, GRIB and BUFR datasets now have Python interfaces.

## Viewing SAF products

In summary, my goal was to visualise all the SAF products from the providers listed in Table 1 against a basemap of coastlines using a Windows based system. To achieve this, I will describe the software applications and methods that I used. With ease of use in mind, my first choice of application(s) were those at the top of Table 2 and I would then work my way down the table if these proved to be ineffectual. I did not consider the applications listed under the Scientific Analysis and Presentation category as these seemed better suited to professional users..

## Ocean & Sea Ice (OSI)

I have started with the OSI products as I think that these are the easiest to visualise. The data is delivered as netCDF4 files with a straightforward two dimensional

structure and full geo-referencing using the *Geographic Co-ordinate System*. As a result, I established that all the generic viewers are able to provide OSI images complete with basemap where the capability exists.

## Combining Files (NCO)

Two of the OSI products designated as OSI-204-c and OSI-208-b (search on EUMETSAT Product Navigator) are derived from Low Earth Orbit (LEO) satellites and provide global coverage. The data is supplied in chunks as a sequence of files, each containing three minutes worth of information, with up to 480 files per day. Whilst each file could be viewed individually, I wanted to combine them in some way to produce a single global image. Using a generic viewer to do this was not practical so the only obvious alternative was to combine all the individual netCDF files into a single larger one.

I identified two toolsets that specialise in manipulating netCDF files which were the *Climate Data Operators* (CDO) and *netCDF Operators* (NCO) in the hope that one of them would be able to perform the spatial combination. Although both toolsets are designed for use under *Linux*, my initial research suggested that they could also be used under *Windows*. General purpose software could also be used to combine files but I was unable to find a suitable script and do not currently have the knowledge to produce one but I'll keep looking.

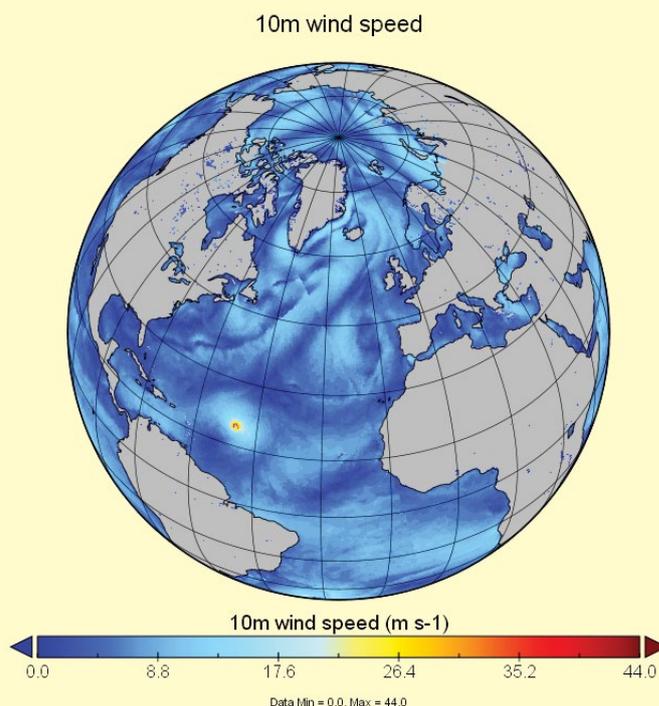


Figure 1 - An OSI 10 m global wind image derived from 100+ individual files using NCO and generated with Panoply. The red dot is Hurricane Larry

To cut a long story short, I rejected CDO because it could not be used with Windows as far as I could tell and NCO was available as a native Windows build. I also established that NCO could combine files spatially following experiments with the Linux version and a BASH shell script to automate the process. But when I tried to replicate the operation on the Windows build using a batch file, I

ran into problems. Firstly, the Windows command shell does not have native support for a feature called 'wildcard expansion', although I was able to find a workaround. More seriously, the Windows build of NCO did not properly replicate the Linux version and proved to be unusable in my application. I then discovered that NCO had been released as a *Cygwin* package so I experimented with this option and received excellent results. The *Cygwin* version worked perfectly and also allowed me to use my original BASH shell scripts under Windows with necessary changes to path names. An example of an image derived from combining multiple files is shown in Figure 1.

The Windows Subsystem for Linux (WSL) could be used for both CDO and NCO but this solution seemed like overkill to me and in any case, my version of Windows didn't support it.

Another product designated as OSI-205-a covers the north and south high latitude regions and is also transmitted as a sequence of three minute files. These can also be combined using NCO to form a single netCDF file.

### Combining Files (McIDAS-V)

The OSI product designated as OSI-410 is derived from LEO satellites and provides an excellent view of the sea ice concentration around the poles. The received files contain either a half orbit or a full orbit's worth of data depending on the particular satellite type. As each file only covers a limited segment of the polar regions, they need to be combined to provide a full picture of the ice coverage. I was unable to combine the files using the NCO toolset (I received an error message that I could not resolve) so I looked for an alternative solution. I was aware that a daily composite image was already transmitted but I wanted to find out how to do it myself as an academic exercise.

As mentioned earlier in the article, McIDAS-V is able to load and display multiple files on a single canvas thereby combining the images on screen rather than through file manipulation. In practice, I would suggest that this only works for a limited number of individual files but is perfectly feasible with the numbers involved for the OSI-410 product.

For my initial experiments, I created a viewing panel with a basemap and loaded each file manually, but this method quickly became very tedious when dealing with more than half a dozen or so. To speed up the process, I used the scripting capability of McIDAS-V and prepared a couple of scripts using the *Jython* shell to ingest files automatically and project the resultant images on to baseline maps of the polar regions. Two partially populated images are shown in Figures 2a and 2b.

### Land Surface Analysis (LSA)

The LSA data is delivered as HDF5 files with a two dimensional structure and no geo-reference information. If a basemap is required for the images, the viewing application is expected to identify the product contained in a file and provide the missing geo-reference information from its own resources. This is possible because the viewpoint for a given product type is constant so the position of each pixel relative to the Earth remains fixed.

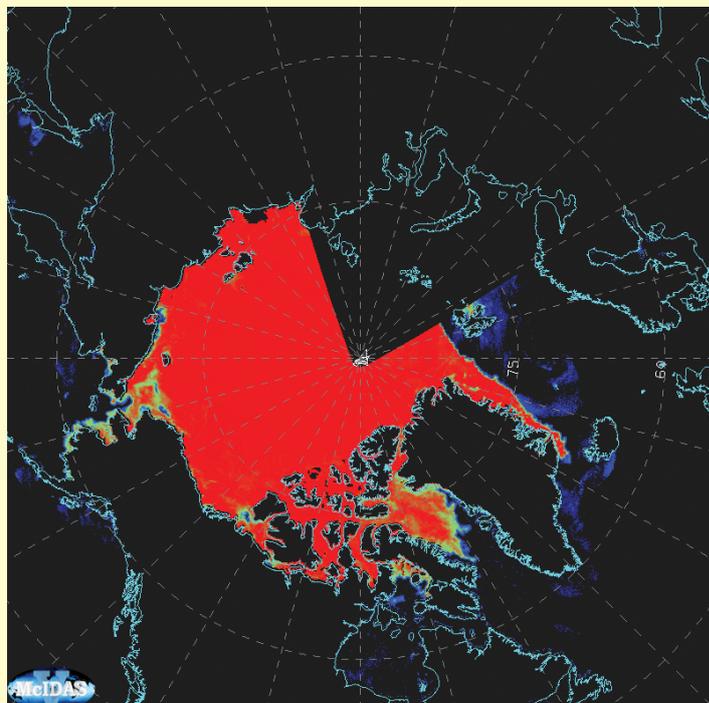


Figure 2a - OSI Arctic polar ice coverage image (incomplete) derived from multiple files containing data from AMSR-2 instrument on GCOM satellite and generated with McIDAS-V

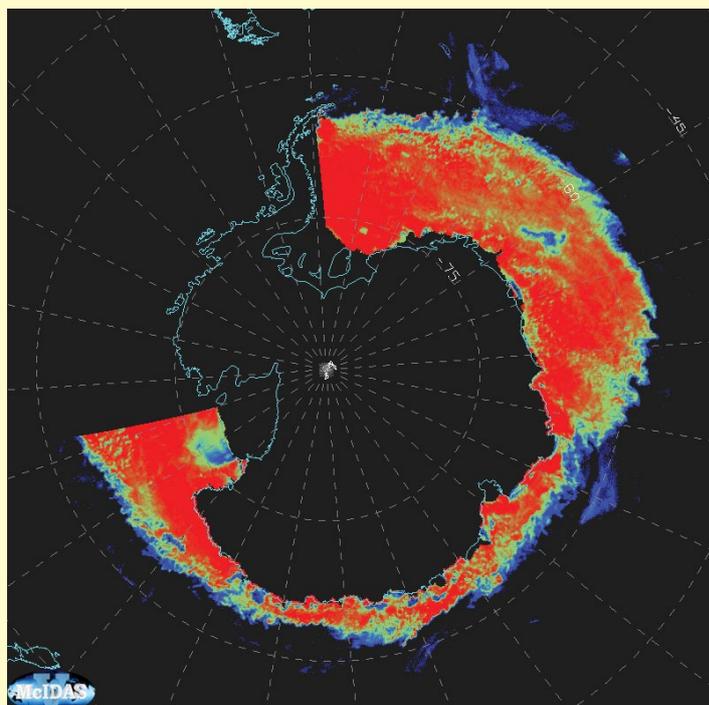


Figure 2b - OSI Antarctic polar ice coverage image (incomplete) derived from multiple files containing data from AMSR-2 instrument on GCOM satellite and generated with McIDAS-V

Products distributed up to 2015 were constrained by processing limitations as described in the following quotation extracted from an LSA document.

*'Due to computational limitations in the early days of the LSA SAF, the MSG derived products generated in the period between 2004 and 2015 were processed into 4 geographical areas within the MSG-Disk. Since 2016, all MSG derived products are produced and available for the SEVIRI full disk. However, some products are still distributed via EUMETCast split into the former 4 geographical regions, mainly due to bandwidth restrictions on the broadcast services.'*

The four regions are Europe, Northern Africa, Southern Africa and South America.

The HDF Viewer from David Taylor was able to visualise some LSA products including the regional versions whilst adding coastline and country boundary outlines but, unfortunately, was not able to cope with the majority of the full disk images. I think that there was a change to the file format for these that the viewer was unable to handle.

I was able to view all of the LSA products (with two exceptions) in a simple two dimensional format without basemap using Panoply and HDFView. The two exceptions were global products derived from LEO satellites (product references H32 and LSA-002) which weighed in with an eye-watering resolution of 36000 x 18000 pixels and could not be handled by these two viewers. However, the ESA SNAP viewer (as suggested by the LSA SAF website) was able to produce images. Note that the H32 product is delivered by the LSA SAF on behalf of the H SAF.

### LSA Geo-referencing

As my goal was to visualise all products including basemaps, I was stubborn enough to try and find a way around the limitations mentioned in the previous section. Further research found a *Python* script in a software repository ([https://gitlab.com/joao.macedo/msg\\_hdf5\\_to\\_netcdf](https://gitlab.com/joao.macedo/msg_hdf5_to_netcdf)) that converted the MSG derived products in HDF5 format into netCDF4 files, adding a geostationary projection co-ordinate system along the way. The resultant images could be projected on to basemaps with Panoply, WCT and QGIS. McIDAS-V had trouble with correct interpretation for some reason but I was able to compensate by modifying an attribute in the resultant netCDF file using the NCO toolset. ESA SNAP did not recognise the projection co-ordinate system so there was no advantage in using this viewer with the netCDF file. An example of the result is shown in Figure 3.

Two of the MSG derived products generated an error with the Python script so I investigated further and found that the cause was surprisingly simple. The metadata contained a single character that was not UTF-8 compliant, causing the Python script to abort. I wrote a very simple Python script to modify the character in the HDF5 file prior to the conversion process and the problem was fixed.

For the two global products, I used two different solutions. The H32 snow product has only 6 possible values per pixel, one of which is water. By creating a custom colour palette in ESA SNAP that allocated a unique colour (such as blue) to the water areas, the coastlines were clearly delineated and I regarded a basemap as unnecessary. An example of the result is shown in Figure 4.

For the LSA-002 product, I used the ILWIS 386 GIS in conjunction with the *GEONETCast Toolbox* to produce an ILWIS image file and accompanying geo-reference file. I was then able to view the image using ILWIS 386 and add coastlines, grid lines and colour interpretation bar at will. An example of the result is shown in Figure 5.

The GEONETCast catalogue is not confined to LSA-002 and is able to process other LSA products as well.

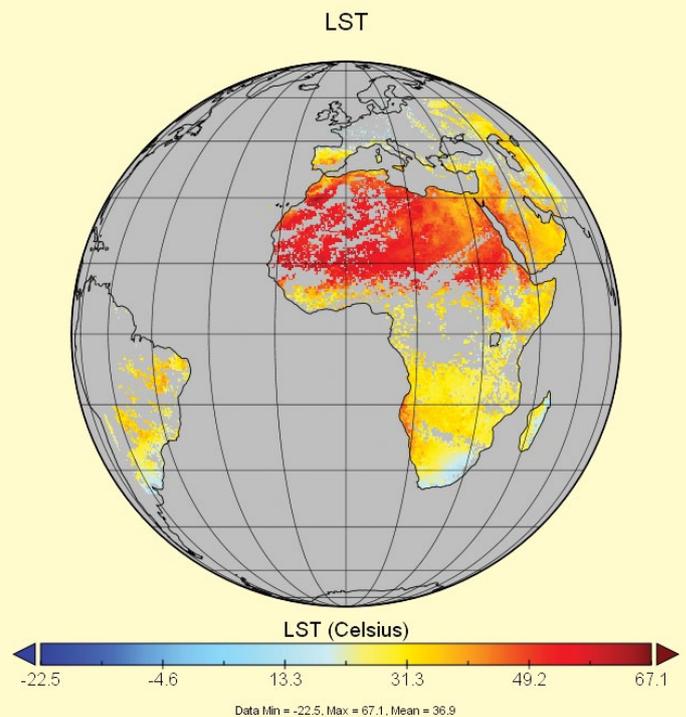


Figure 3 - LSA full disk Land Surface Temperature generated with Panoply after conversion with Python script.

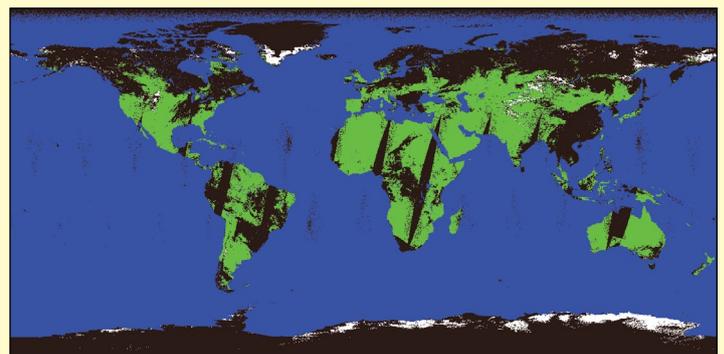


Figure 4 - EPS Daily Snow Cover generated with ESA SNAP. Original resolution was 36000 x 18000 pixels.

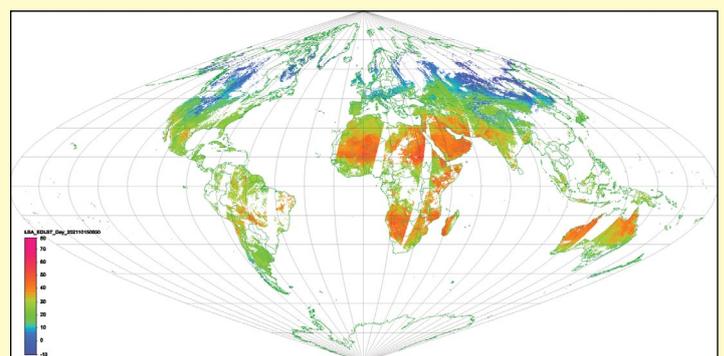


Figure 5- EPS Daily Land Surface Temperature generated with ILWIS 386 and GEONETCast Toolbox. Original resolution was 36000 x 18000 pixels.

### Hydrology SAF (H SAF)

The H SAF data is delivered as netCDF, BUFR and GRIB files and some products are provided as netCDF and BUFR in parallel. I don't know how long this dual arrangement will continue as H SAF has indicated that it is moving towards netCDF and discontinuing BUFR at some point.

NetCDF files are delivered with a straightforward two dimensional structure and full geo-referencing using the *Geographic Co-ordinate System*. I established that all the generic viewers are able to provide OSI images complete with basemap where the capability exists. For BUFR files, the BUFRdisplay viewer was the one that I used.

For GRIB files, my first choice was David Taylor's GRIB Viewer as it is aimed towards EUMETCast products and provided a basemap. For one product that I tried with a designation of H14, it was not able to open the file, possibly because it lacked the necessary tables. Of the generic viewers, Panoply, McIDAS-V and WCT were also capable of viewing GRIB files although there was a potential quirk with precipitation products H03 and H05. The range of valid data within these two products included a rainfall value of zero and this can occupy a lot of the total dataset. The generic viewers populated the image with areas covered by this zero rainfall, adding a lot of extraneous detail that detracted from active rainfall locations. This did not happen with the GRIB Viewer and I assume that it applies a filter to the data to remove zero rainfall areas from view. In addition, the generic viewers also displayed the default rainfall values as kg/m<sup>2</sup> per second, or kg per m<sup>2</sup> which is not particularly meaningful although units can be changed in McIDAS-V.

I haven't found a way to filter the data on the generic viewers so that they ignore zero values but I have found a solution in colour table configuration. McIDAS-V has a built-in colour table editor that includes a transparency property and allows a background to 'shine through' defined colour ranges. This property can be used to hide the zero rainfall areas or any value below a given threshold. With Panoply and WCT, the range of displayed values can be altered but the full colour table then applies to this new range and they don't have a table editor. I think that the best solution here is to try and find a colour table that gives the best visual appearance.

### Combining Files (McIDAS-V & BUFR)

H SAF files for product H01 and H02 contain data covering a partial orbit of a LEO satellite and the most informative images are provided by viewing multiple files simultaneously. For the time being, these files are available in both netCDF and BUFR format. BUFRdisplay already has the ability to view multiple files so no further action is needed for this viewer. As far as the netCDF files are concerned, I have not managed to combine them using the NCO toolset and I don't know if this is even possible. My immediate solution was to combine them with McIDAS-V, employing the same method that I used for the OSI-410 product previously mentioned and assisted by a Jython script. Because the images derived from the individual files overlapped frequently, I needed to adjust the associated colour table to stop "wash-out" in the overlapping areas and further work is needed for this aspect. An example of the result is shown in Figure 6.

I note that product H08 also uses parallel transmission of netCDF and BUFR files but I have yet to investigate the merging of netCDF files in this instance. I don't think that the NCO toolset can cope because of the variation in dimension sizes between each file.

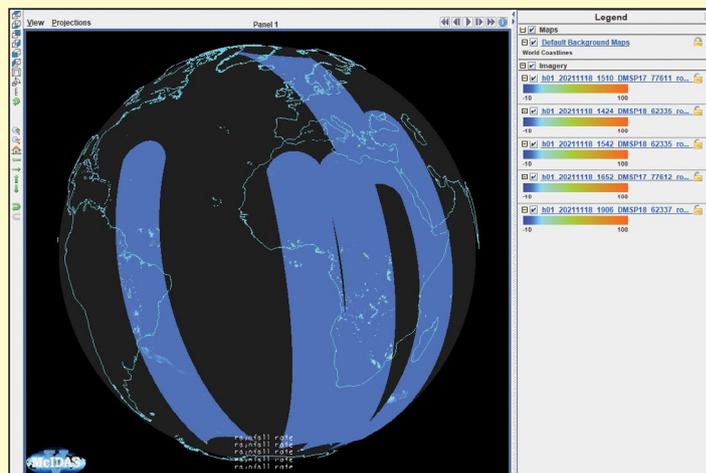


Figure 6 - H SAF Precipitation Rate at Ground derived from DMSP satellites in multiple passes generated by McIDAS-V

### NowCasting (NWC)

The NWC products available over EUMETCast relate to cloud properties and are split into two distinct streams - Geostationary(GEO) and Polar Platform System (PPS) represented by LEO satellites. Unusually, the NWC products do not have their own EUMETCast channel and the data is disseminated over Data Channel 3 for GEO products and Data Channel 1 for PPS products (these channel names will change in 2022).

### GEO

The GEO data is delivered as netCDF4 files with a two dimensional structure and a geostationary projection co-ordinate system that was not recognised by any of the generic viewers. Two products are available—one with cloud type and the other with cloud altitude, pressure and height properties. Each property also has an associated colour palette included in the product file. I was able to view the products in a simple two dimensional format without coastlines using Panoply, HDFView and ESA SNAP although none of these recognised the colour palette data and used their own defaults instead.

Looking more closely at the netCDF file, I sensed that extra data was needed to allow the generic viewer to recognise the projection co-ordinate system. Using NCO, I added some extra metadata to a GEO file and found that Panoply was then able to project the images on to a basemap correctly but other viewers could not. This is probably not surprising as I was manipulating netCDF files without much clue as to what I was doing, but it did show that there was room for more experimentation.

Further research revealed that a tool called NWCPY (this is a pure *Python* script) is available via the NWC SAF website. This script generates images from GEO products exactly like those shown on the website (<https://www.nwcsaf.org>) including the colour interpretation bar at the bottom.

### PPS

The PPS data is delivered as netCDF4 files over the EUMETCast EARS channel with a two dimensional structure and a geographic projection co-ordinate system. Each file represents one minutes worth of data. However, the geographic co-ordinates are only supplied for one pixel

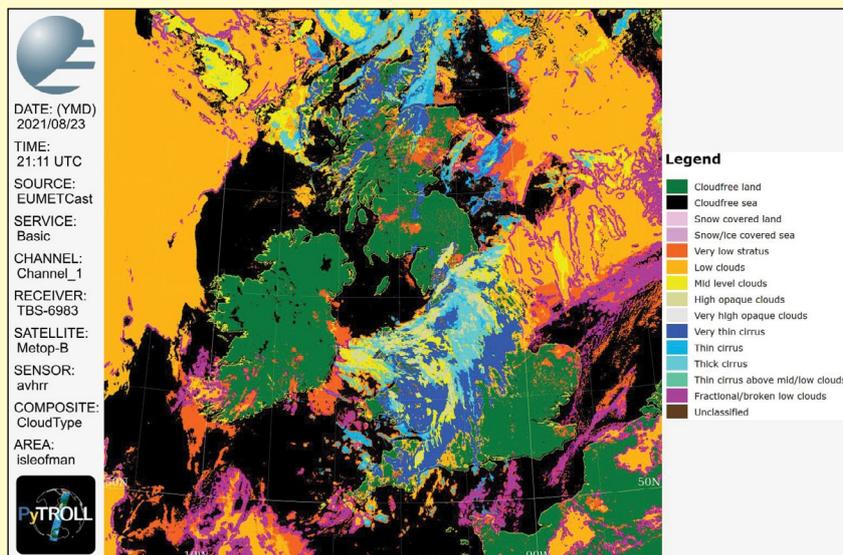


Figure 7 - NWC PPS Cloud Type derived from Metop-B generated by Python using SatPy package and based on script provided by Ernst Lobsiger in PyTroll Starter Kit.

in every five for both the X and Y directions, presumably to save bandwidth. The same two products as GEO are available.

To produce a decent image, it was clear that I needed to join a number of files together and provide a basemap otherwise it would be extremely difficult to geo-locate cloud images if no recognisable land features were visible. The partial nature of the co-ordinates meant that none of the generic viewers was able to supply a basemap, so the only answer was going to be general purpose software and that was beyond my capabilities. I could find nothing on the website of any help. Back to research for an answer.

It turns out that *PyTroll* was started by one of the meteorological organisations that produces the NWC SAF data and that the Satpy package has a reader for the NWC PPS format. Sample skeleton scripts for the PPS products are available on the PyTroll examples software repository (<https://github.com/pytroll/pytroll-examples>) under nwcsaf-tutorials. I couldn't open the relevant Jupyter Notebook file directly so I resorted to the online nbviewer instead.

For a very good article on the history of **PyTroll**, I can recommend a paper in the Bulletin of the American Meteorological Society, July 2018. (<https://journals.ametsoc.org/view/journals/bams/99/7/bams-d-17-0277.1.xml?rskey=S5M8pG&result=1>).

Using PyTroll and building on these scripts to define regions of interest and image decoration would have been beyond my capability were it not for the excellent PyTroll/SatPy Starter Kit information provided by Ernst Lobsiger (thanks Ernst) and published on the MSG-1 Groups website. I eventually generated combined day/night scripts to produce cloud type images for METOP-B and NOAA-19, the two satellites currently providing PPS products. An example image is shown in Figure 7.

### Atmospheric Composition (AC)

The final SAF products that I tried to were those disseminated by the AC SAF. This provides information about trace atmospheric gases such as ozone, NO<sub>2</sub>, SO<sub>2</sub>,

and HCHO. The data is delivered as both BUFR and HDF5 files with an odd structure. The SO<sub>2</sub> data should be useful in the monitoring of volcanos.

For viewing the BUFR files, I used BUFRdisplay as the go-to application.

I determined that some of the HDF5 files had a one dimensional structure representing a data stream provided by a scanner that was swinging from side to side, and it was clear that none of the generic viewers, or any non-bespoke application for that matter, would be able to interpret the data. This was a definite general purpose software task so I embarked on a research program yet again to find a solution.

Eventually, I found some suitable *Python* scripts on a EUMETSAT software repository (they don't make it easy) at (<https://gitlab.eumetsat.int/eumetlab/atmosphere/atmosphere>). I have only managed to produce a small image of a single file on a map background to date so this SAF is very much a work in progress.

### Conclusion

My quest to visualise as many SAF products as possible has been an interesting journey. Some of the products are disseminated only once per day and so there are a number that I have probably not tested but I hope to investigate them at some point.

For BUFR and GRIB files, I have concluded that the best viewing applications are BUFRdisplay and GRIB Viewer respectively with a small amount of backup from generic viewers for the latter. For netCDF and HDF5 files, however, the situation is completely different. The self-describing nature of these file types means that there can be a wide variation in their structure—a bit like defining the grammar and vocabulary for a language and then allowing authors to write whatever they want. To stretch the analogy further, one or more of the generic viewers can provide an abstract (and sometimes more) but to guarantee reading the complete text, general purpose software such as Python or specialist applications are needed.

## Currently Active Satellites and Frequencies

Polar APT/LRPT Satellites			
Satellite	Frequency	Status	Image Quality
NOAA 15	137.6200 MHz	On	Good
NOAA 18	137.9125 MHz	On	Good
NOAA 19	137.1000 MHz	On	Good <sup>[1]</sup>
Meteor M N1	137.0968 MHz	Off	Dead <sup>[8]</sup>
Meteor M N2	137.1000 MHz	On	Good
Meteor M N2-2	137.9000 MHz	Off	System failure <sup>[12]</sup>

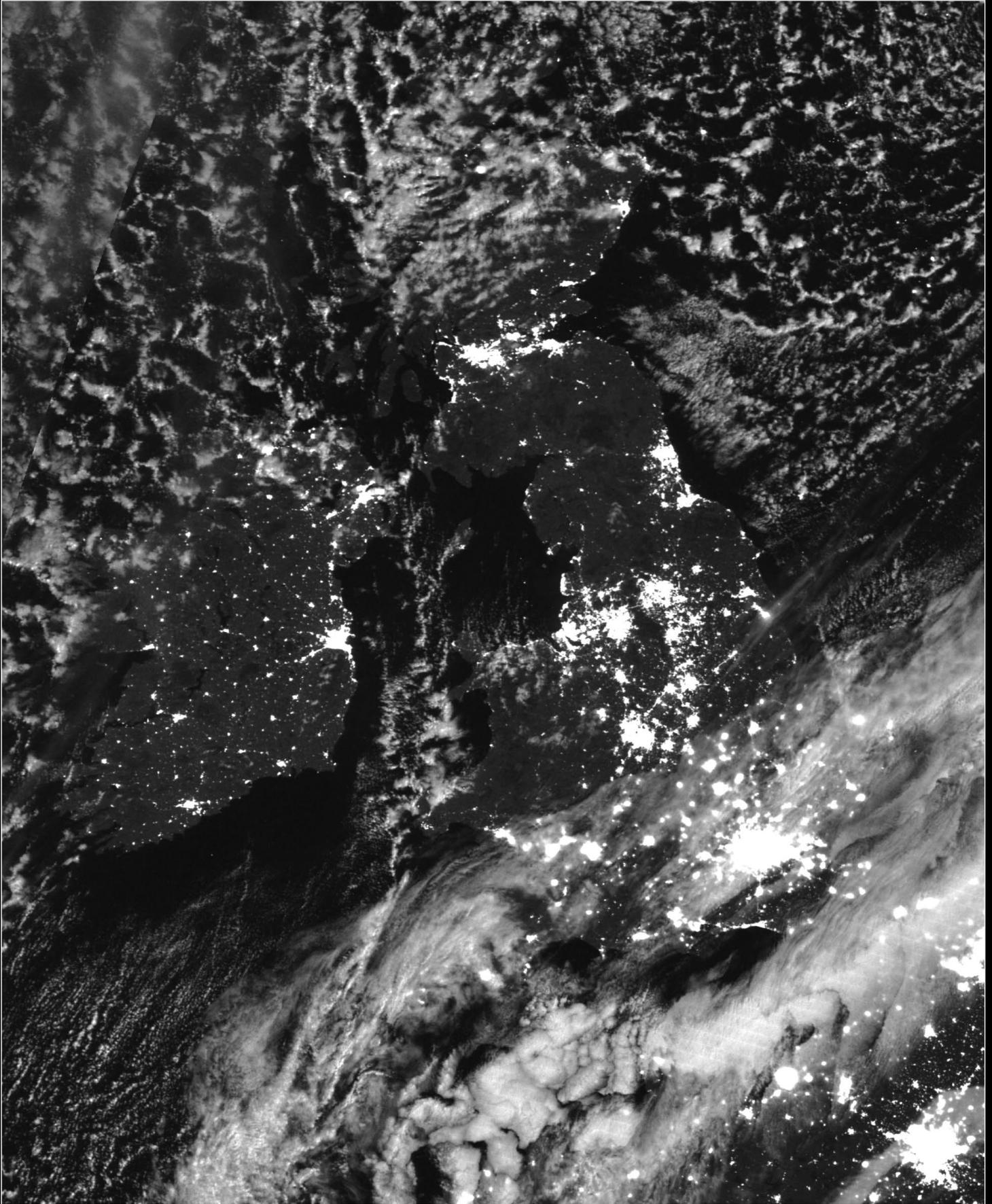
Polar HRPT/AHRPT Satellites				
Satellite	Frequency	Mode	Format	Image Quality
NOAA 15	1702.5 MHz	Omni	HRPT	Weak
NOAA 18	1707.0 MHz	RHCP	HRPT	Good
NOAA 19	1698.0 MHz	RHCP	HRPT	Good
Feng Yun 1D	1700.4 MHz	RHCP	CHRPT	None: Device failure
Feng Yun 3A	1704.5 MHz	RHCP	AHRPT	Inactive <sup>[2,10]</sup>
Feng Yun 3B	1704.5 MHz	RHCP	AHRPT	Active <sup>[2]</sup>
Feng Yun 3C	1701.4 MHz	RHCP	AHRPT	Active <sup>[2]</sup>
Metop B	1701.3 MHz	RHCP	AHRPT	Good
Metop C	1701.3 MHz	RHCP	AHRPT	Good
Meteor M N1	1700.00 MHz	RHCP	AHRPT	Dead <sup>[8]</sup>
Meteor M N2	1700.0 MHz	RHCP	AHRPT	Good
Meteor M N2-2	1700.0 MHz	RHCP	AHRPT	Active <sup>[12]</sup>

Geostationary Satellites				
Satellite	Transmission Mode(s)		Position	Status
Meteosat 8	HRIT (digital)	LRIT (digital)	41.5°E	IODC
Meteosat 9	HRIT (digital)	LRIT (digital)	3.5°E	On <sup>[5]</sup>
Meteosat 10	HRIT (digital)	LRIT (digital)	9.5°E	Off <sup>[4]</sup>
Meteosat 11	HRIT (digital)	LRIT (digital)	0°W	On <sup>[3]</sup>
GOES-13	GVAR 1685.7 MHz	LRIT 1691.0 MHz	60°W	Off
GOES-14	GVAR 1685.7 MHz	LRIT 1691.0 MHz	105°W	Standby
GOES-15 (W)	GVAR 1685.7 MHz	LRIT 1691.0 MHz	128°W	On <sup>[6]</sup>
GOES-16 (E)	GRB 1686.6 MHz	HRIT 1694.1 MHz	75.2°W	On <sup>[6,9]</sup>
GOES-17	GRB 1686.6 MHz	HRIT 1694.1 MHz	137.2°W	<sup>[11]</sup>
MTSAT-1R	HRIT 1687.1 MHz	LRIT 1691.0 MHz	140°E	Standby
MTSAT-2	HRIT 1687.1 MHz	LRIT 1691.0 MHz	145°E	On
Feng Yun 2D	SVISSR	LRIT	123.5°E	Backup/Off <sup>[7]</sup>
Feng Yun 2E	SVISSR	LRIT	86.5°E	On
Feng Yun 2F	SVISSR	LRIT	112.5°E	Standby
Feng Yun 2G	SVISSR	LRIT	99.5°E	On
Feng Yun 2H	SVISSR	LRIT	86.5°E	
Feng Yun 4A	HRIT (digital)	LRIT (digital)	99.5°E	On

### Notes

- 1 LRPT Signals from Meteor M N2 may cause interference to NOAA 19 transmissions when the two footprints overlap.
- 2 These satellites employ a non-standard AHRPT format and cannot be received with conventional receiving equipment.
- 3 Meteosat prime Full Earth Scan (FES) satellite
- 4 Meteosat backup Full Earth Scan (FES) satellite
- 5 Meteosat prime Rapid Scanning Service (RSS) satellite.
- 6 GOES 15 also transmits EMWIN on 1692.700 MHz  
GOES 16 also transmits EMWIN on 1694.100 MHz  
GOES 17 also transmits EMWIN
- 7 There has been no imagery from Feng Yun 2D since June 30, 2015. Since Feng Yun 2G is operating from the same position (86.5°E), it is likely that FY-2D is now in standby as a backup satellite.
- 8 On March 20, 2016, Meteor M1 suffered a catastrophic attitude loss, frequently pointing its sensors towards the sun. The following day all signals ceased and it seems highly probable that this satellite is now incapable of imaging the Earth.
- 9 GOES Rebroadcast (GRB) provides the primary relay of full resolution, calibrated, near-real-time direct broadcast space relay of Level 1b data from each instrument and Level 2 data from the Geostationary Lightning Mapper (GLM). GRB replaces the GOES VARIABLE (GVAR) service.
- 10 Although Feng Yun 3A's status is recorded on the wmo-sat website as 'inactive (end of operation)', it continues (as of June 2018) to transmit imagery.
- 11 GOES 17 is expected to start operations during January 2019.
- 12 Following a collision with a micrometeorite, the power system aboard Meteor M2-2 has been compromised. AHRPT is still being transmitted when the solar panels are sunlit, but there is insufficient battery power to enable the LRPT stream..

## The Calm Before Storm Arwen



It's the early hours of November 26, 2021, a cool, cloudless night less than 24 hours before the arrival of Storm Arwen. NOAA's Suomi-NPP satellite imaged this scene, picking out dozens of towns and cities as bright white spots using its VIIRS Day/Night Band. The following day, winds of up to 150 kph scoured the eastern coasts of Scotland and northeast England, downing trees, cutting communications, and leaving thousands of households without power.

Image: NASA Worldview Snapshots (<https://wvs.earthdata.nasa.gov/>)