The GEO Quarterly

Group for Earth Observation

GEO Group for Earth Observation

The Independent Amateur Quarterly Publication for Earth Observation and Weather Satellite Enthusiasts

52

December 2016

Inside this issue . .

Paul Geissmann, a member based in Switzerland, has provided an interesting essay relating to the first alpine weather station in the Swiss Alps.

The main article this quarter comes from NASA Earth Observatory, a detailed discussion on Sea Ice and how it is responding to Global Warming.

For readers just starting out with NOAA APT reception, Michael K Butler has compiled a guide to everything you need, amply illustrated by images processed using WxXtoImg.

Mike Stevens has been keeping busy downloading Sentinel and Suomi data via EUMETCast, and several of his best images are illustrated in our pages. Mike has also trialled yet another DVB S2 tuner, the USB TBS 5927.

It's been a busy year for GEO Outreach, attending rallies, and in this issue we carry Francis Bell's report and pictures from the recent London Radio and Computer Rally at Kempton.

And of course there is the usual eclectic mix of short features from NASA's Earth Observatory.

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Editorial

Les Hamilton

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As another year comes to a close we have a stellar 56-page issue to provide you with Festive Season reading. For newcomers to satellite imaging, Michael K Butler has compiled to everything you need to know about APT reception, still the most popular entry-level route, into an illustrated article on page 19.

The topic of Climate Change is headlined to some depth starting with the article ‘How do we know’ on page 14, followed by a seminal treatise on Sea Ice from experts at NASA Earth Observatory. The thread continues by looking at a massive ice avalanche in Tibet and ice retreat in west Antarctica.

I would like to remind you that, as a subscriber to GEO Quarterly, you will automatically also receive a printed version of this magazine in addition to this PDF version.

Finally, a big thank-you to everyone who has contributed to GEO Quarterly throughout 2016. Material for articles continues to be hard to come by and the Editor is always pleased to hear from any reader who feels they have something to contribute.

Everyone on the GEO Management Team wishes every reader the very best Christmas and New Year wishes as we look forward to the year ahead.

Copy deadline for the December issue of GEO Quarterly is Sunday, February 26, 2017.

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The GEO Report

Francis Bell

Without reservation, I offer my usual thanks to members who have contributed to our group over the last quarter, particularly those who contributed to this Quarterly, and to our Editor for his work in compiling the materials into a professional format of which we can all be proud. At rallies and other meetings where our Quarterly is on show I continue to be impressed with the compliments received by the general public.

The above paragraph is followed by the usual request for members to contribute appropriate, material for the Quarterly whenever possible. With new satellite data constantly becoming available it's a great help if technical information and experiences can be shared within our group. I for one would feel paralysed without this source of information even with the Internet in the background.

In addition to the ongoing request for Quarterly copy there are two other areas to which I would like to draw your attention.

GEO Symposium 2017

Most years since our formation, GEO has held a one-day annual meeting, usually a busy day with topical technical presentations, followed by our members AGM. Many of these meetings have been held at the *National Space Centre* (NSC) Leicester but also at EUMETSAT's HQ in Darmstadt, Germany and once at *Surrey Satellite Technology* (SSTL), Guildford. In my last report, in GEO Quarterly 51, as a measure to help plan for the forthcoming year, I did ask for feedback from members with their preferred ideas for a meeting in 2017, plus a venue. Unfortunately I have had little feedback, hence a decision relating to a 2017 meeting is difficult, but if such a meeting were to take place, arrangements have to be made in good time. I do note that, over the years, the number of members attending these meetings has declined, but attendance is important and consistently represents about 10% of our total membership.

Please let me know if you have a preferred option for a GEO 2017 meeting. Some option are:

- NSC in April/May
- EUMETSAT in late June
- SSTL which could include a visit to their satellite assembly facilities on a date and time table acceptable to all concerned
- Any other suggestion for a location and time which may be appropriate.

Please email Francis Bell at:

francis@ geo-web.org.uk

with your preferences or ideas.

Widening our Membership

I think we all recognise that our GEO membership numbers have declined in recent years. My feeling is that the increasing access to a wealth of satellite data and other information via the Internet is so easy and widespread that it has become an alternative to direct image reception for some people. Of course I use the Internet myself, and would be sealed in a vacuum without it but I have never found this an alternative to the challenge and satisfaction when accessing direct reception of satellite images from space using my own equipment.

Currently our membership numbers are:

UK	165
Europe	78
USA	13
Rest of World	20

a grand total of 276.

It would be great if we could increase this membership, not just for the sake of numbers, but for the potential it will generate to widen and share our mutual interests in Earth observation. This may be an appropriate time for promoting GEO membership because of the widespread interest in space science that Tim Peake has generated with his six months aboard the ISS. It would also be great to have some new people on the GEO Management Team, who could exploit this interest and use their contacts with education, science, amateur radio or other technical groups, and I would encourage their membership and contributions to our group.

We do earnestly need one or two more people to encourage and promote GEO together with increased membership so, if you think you can help in any way, please contact Francis Bell by email:

francis@geo-web.org.uk

In these days of increasing public interest in space science GEO has a great opportunity to respond supportively by increasing its membership. If you can possibly respond to the above text in a positive way then I'm sure there will be many winners.

I envisage a new promotion officer(s) roles as fulfilling one or more of the following roles:

1. To promote GEO as an organisation using web, social media and other media such as magazines; to ensure GEO has at least a weekly presence on the Amateur Radio/Weather observation scene with a view to increasing membership and participation.
2. To be an active member of GEO-M taking part in management meetings.
3. To assist with events such as rallies and help contribute to the running of our annual symposium.
4. To be sensitive to the ever broadening access to earth observation data. Support personal and educational interests beyond live data reception by offering guidance to the new sources of data which can now be accessed via the Internet.

GEO Quarterly – Back Issues

I have recently been in touch with a GEO member who wishes to complete his collection of printed GEO Quarterlies. I have been able to supply him with some back issues which were missing from his collection but I'm unable to find a copies of GEO Quarterlies 24,27 and 31. I know these are available as PDF files via our web site but I'm sympathetic to someone who wants the printed Quarterly to complete a collection. If any member has one or more of these Quarterlies, and is willing to part with them, please email me at ***francis@geo-web.org.uk*** or telephone 01483 416897. By arrangement, postage costs can be covered and, say, £2.00 for each Quarterly. I hope you can help.

A Quarterly Challenge

In addition to the Quarterly Question which has been popular with members ever since our first publication, I thought it might be interesting on this occasion to issue an additional challenge to readers. I had the idea when reading about GEOSS's new Web Portal—see page 30 of this Quarterly. Contained in the introductory text for the Portal it states that the new system permits individuals to use simple multi criteria searches using only 'a few clicks' to find specific data or images.

I haven't tried this myself yet but the challenge to readers this quarter is to use this GEOSS web Portal to find your own specific data or images. It is not satisfactory to roam around the almost infinite data available and say 'Oh that's interesting' but rather have a specific target before beginning a search. So the challenge is to find a visible spectrum image of one of these:

- Sydney Harbour
- Singapore
- the Panama Canal or
- the island of Malta.

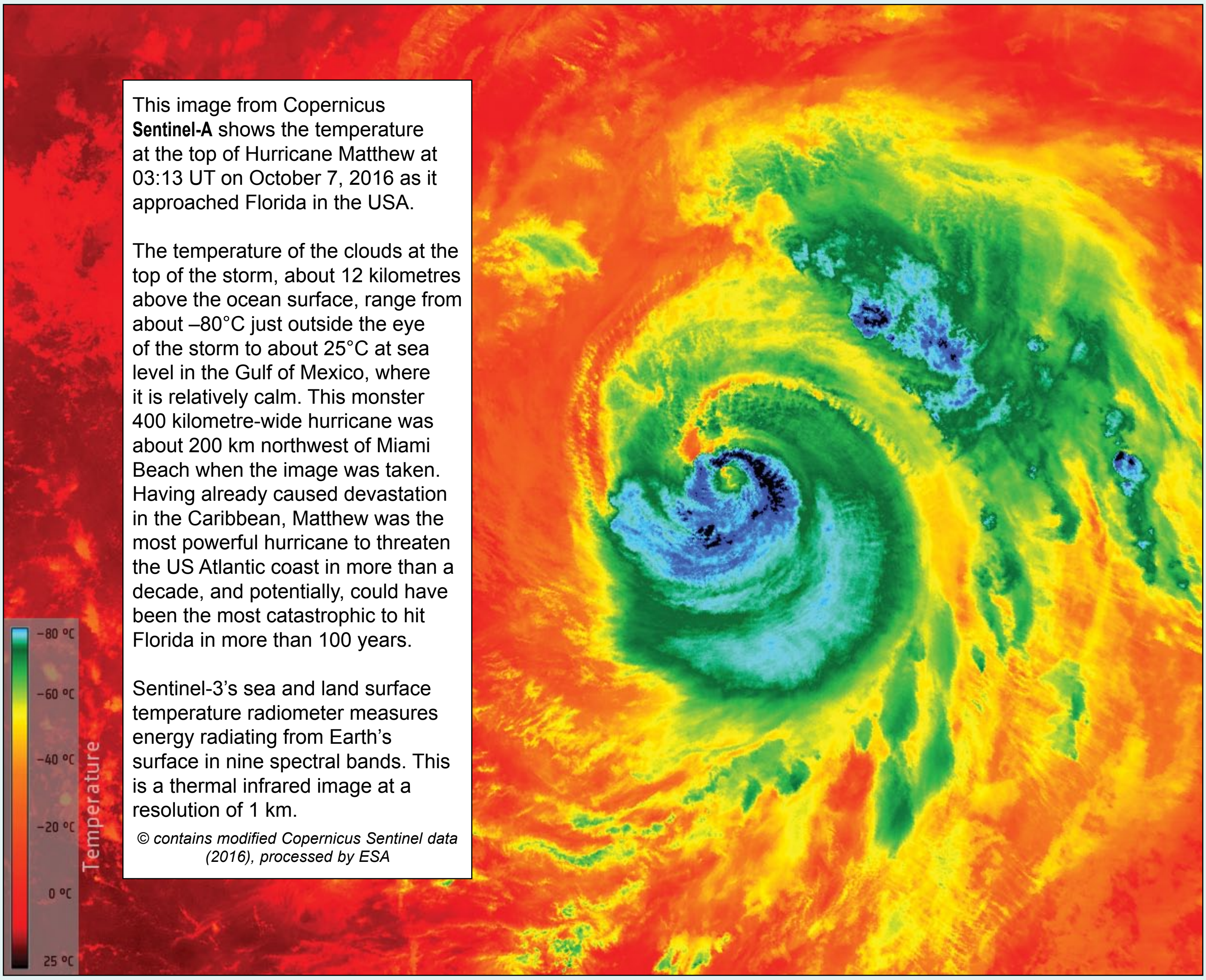
Alternatively, you can search for anything in which you are interested so long as it's predefined by yourself and you don't just come across it by accident.

Please send your images, with appropriate notes relating to your search, to GEO's editor at

editor@geo-web.org.uk.

Eye of the Storm

European Space Agency



This image from Copernicus **Sentinel-A** shows the temperature at the top of Hurricane Matthew at 03:13 UT on October 7, 2016 as it approached Florida in the USA.

The temperature of the clouds at the top of the storm, about 12 kilometres above the ocean surface, range from about –80°C just outside the eye of the storm to about 25°C at sea level in the Gulf of Mexico, where it is relatively calm. This monster 400 kilometre-wide hurricane was about 200 km northwest of Miami Beach when the image was taken. Having already caused devastation in the Caribbean, Matthew was the most powerful hurricane to threaten the US Atlantic coast in more than a decade, and potentially, could have been the most catastrophic to hit Florida in more than 100 years.

Sentinel-3's sea and land surface temperature radiometer measures energy radiating from Earth's surface in nine spectral bands. This is a thermal infrared image at a resolution of 1 km.

Quarterly ? Question

Francis Bell

Quarterly Question 51

My thanks to those members who responded to the last Quarterly Question, which related to the melting of sea ice. The reason for asking the question was to highlight the mistaken belief, often promoted by the misguided public media and others, that the melting of sea ice will lead to a rise in sea level.

The point is that if a piece if ice, no matter how large or small, is floating on water it will displace its own mass of water: hence, when it melts, there will be no change of water volume or level.

In the case of this Question, I did say to ignore temperature and salinity changes which may be factors but will only contribute minutely to volume changes.

The above comments do not relate to the massive ice caps on Greenland and Antarctica, which are several kilometres thick, or to the ice on high mountains and their retreating glaciers. The melting of this ice, which is currently happening, does significantly contribute to an overall rise in sea level. But not the floating sea ice.

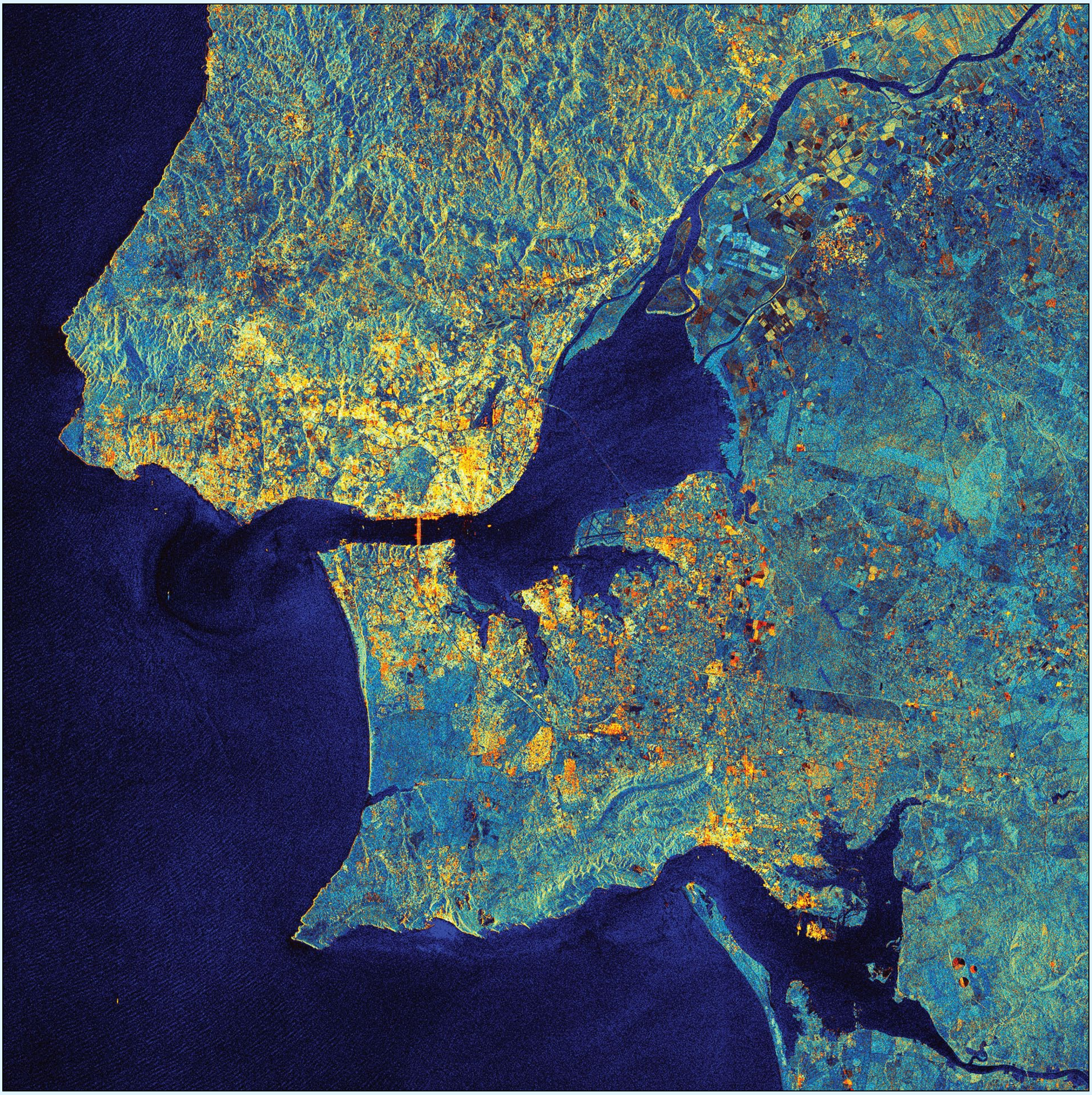


Figure X - The scale of this image is about 75 x 75 km. An iconic bridge joins its two halves together.
Credit: Sentinel-1A image © ESA 2015

Quarterly Question 52

This question relates to the two images shown in Figures X and Y. ESA have a short TV programme which they routinely broadcast on a Friday morning, and often the subject covered relates to their '*Image of the Week*', which is available before their programme. Recently, their images have been from the Sentinel satellites which are providing multispectral high resolution images of the earth. On a regular basis I look at these images and if I find one particularly interesting I sometimes save it to a small archive which I am accumulating just for my own interest.

I was recently browsing through some of these images and two came to my attention because they both illustrate major European cities located on their respective coasts. I guess I'm like other people: if I see an image showing a coastal outline, I can often identify the location. But without that reference it can be difficult for me to immediately identify what I'm looking at. Of course there is an ESA title to go with each image, but that's not the point. The challenge is to identify the image independently. Although I have visited both countries I have not visited the cities in this question.

This Quarterly Question is to give the current names of the two major cities shown in these two satellite images.

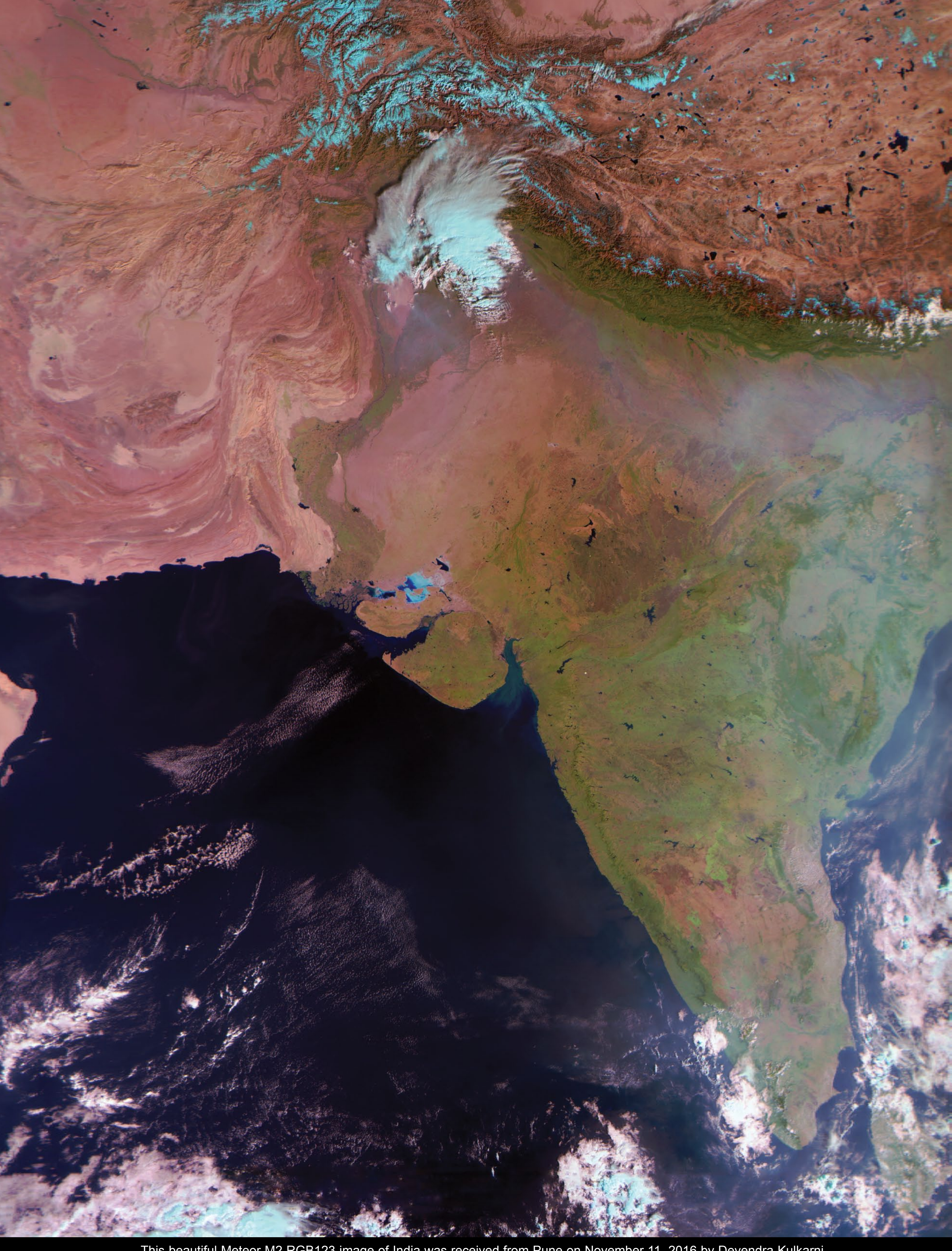
Both of the cities are in Europe. One of them is the capital of its country and the other, which quite recently has had three different names, used to be the capital of its country. The fact that these cities are—or have been—capitals is not surprising, as many countries throughout the world have their capitals on the coast, or just inland via a major river or estuary, for historical maritime communication reasons. Note the difference in scale of the two images. In the case of figure Y, several small cities may be present but the one in question is conspicuous and shown slightly towards upper right in the image. Another clue is that this city's latitude is exactly 60° north. An additional point of interest might be to name the other less obvious capital cities which can be identified in Figure Y.

Answers, just giving the names of the two cities please, should be sent by email to Francis Bell at

francis@geo-web.org.uk

before Sunday, February 19, 2017.

Figure Y -The scale of this image is about 600 x 600 km and the city in question lies slightly upper right of the centre.
Credit: Envisat MERIS image © ESA 2003

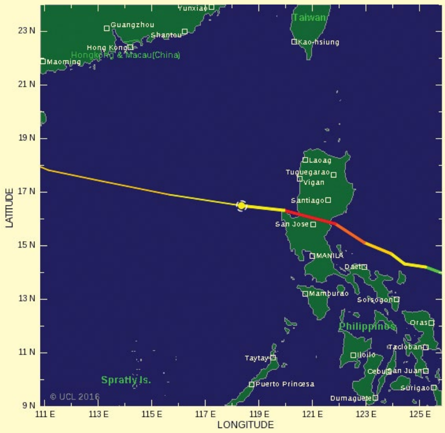


This beautiful Meteor M2 RGB123 image of India was received from Pune on November 11, 2016 by Devendra Kulkarni.
On rare occasions, Meteor M2 transmits simultaneously on channels 1, 2 and 3, making colour composite images like this possible.

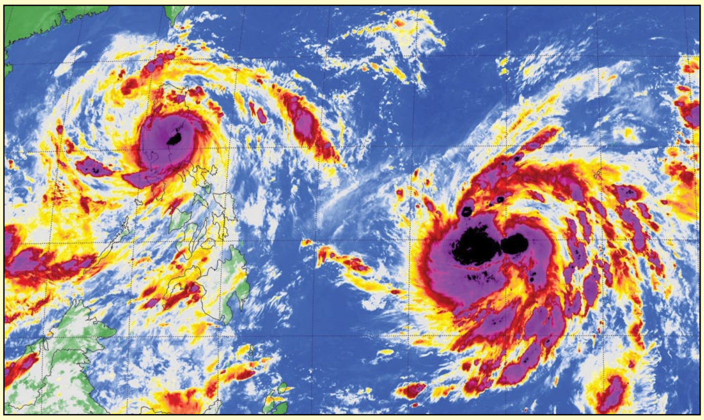
Two Typhoons strike the Philippines within a Week

John Tellick

The Philippines do seem to come in for more than their fair share of typhoons, with the NW Pacific region seemingly quite a breeding ground for these tropical storms. *Typhoon Sarika* hit the Philippines on Sunday October 16, leaving at least two dead, houses destroyed, trees uprooted, roads blocked and electric supply cables brought down.

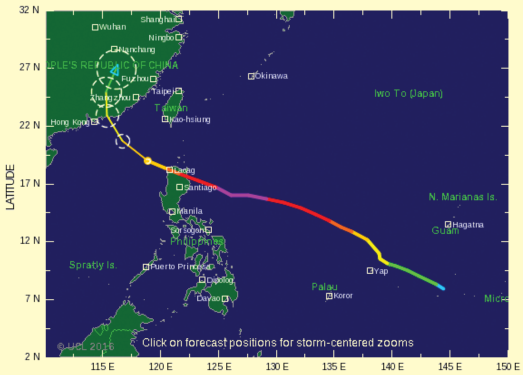


The track of Typhoon Sarika
Credit: www.tropicalstormrisk.com

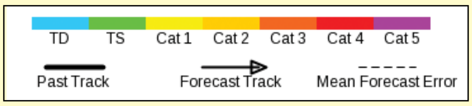


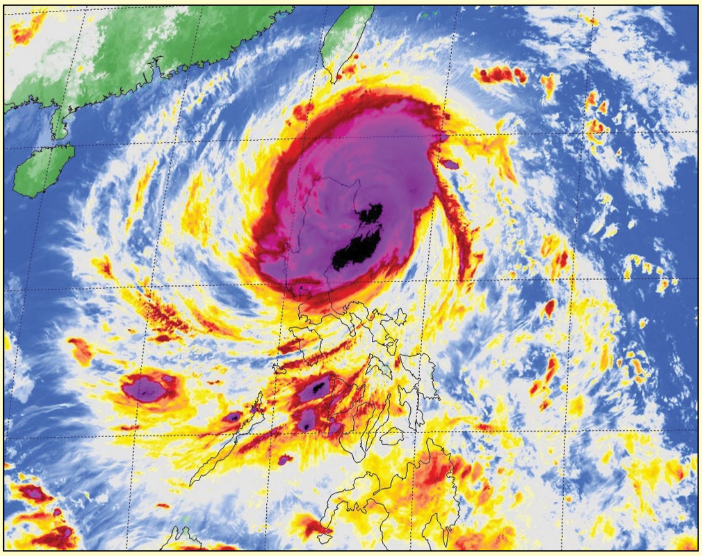
The centre of *Sarika* making landfall on October 16 with *Haima* just a few days away heading towards the same area of the Philippines
Image © EUMETSAT 2016

Typhoon Haima arrived on October 19, the centre of the storm tracking somewhat further to the north of Sarika's path, again destroying houses, uprooting trees and power cable posts and causing flooding and the loss of at least four lives. Both were Category-4 typhoons when they made landfall.



The track of Typhoon Haima
Credit: www.tropicalstormrisk.com



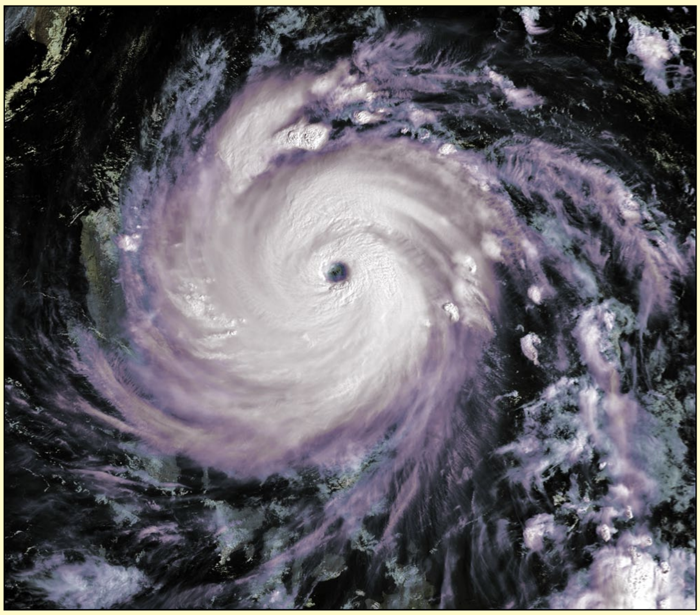


The centre of Haima making landfall on October 19
Image © EUMETAT 2016

Haima had earlier reached Category-5 '*Super Typhoon*' status whilst approaching the Philippines, prior to making landfall.

The Philippines experience between 15 and 20 typhoons during the monsoon season, which begins in June and ends in November. In November 2013, *Typhoon Haiyan*, one of the most destructive storms to have touched land in the Philippines, left 6,300 dead, more than 1,000 missing and 14 million affected in the central part of the country.

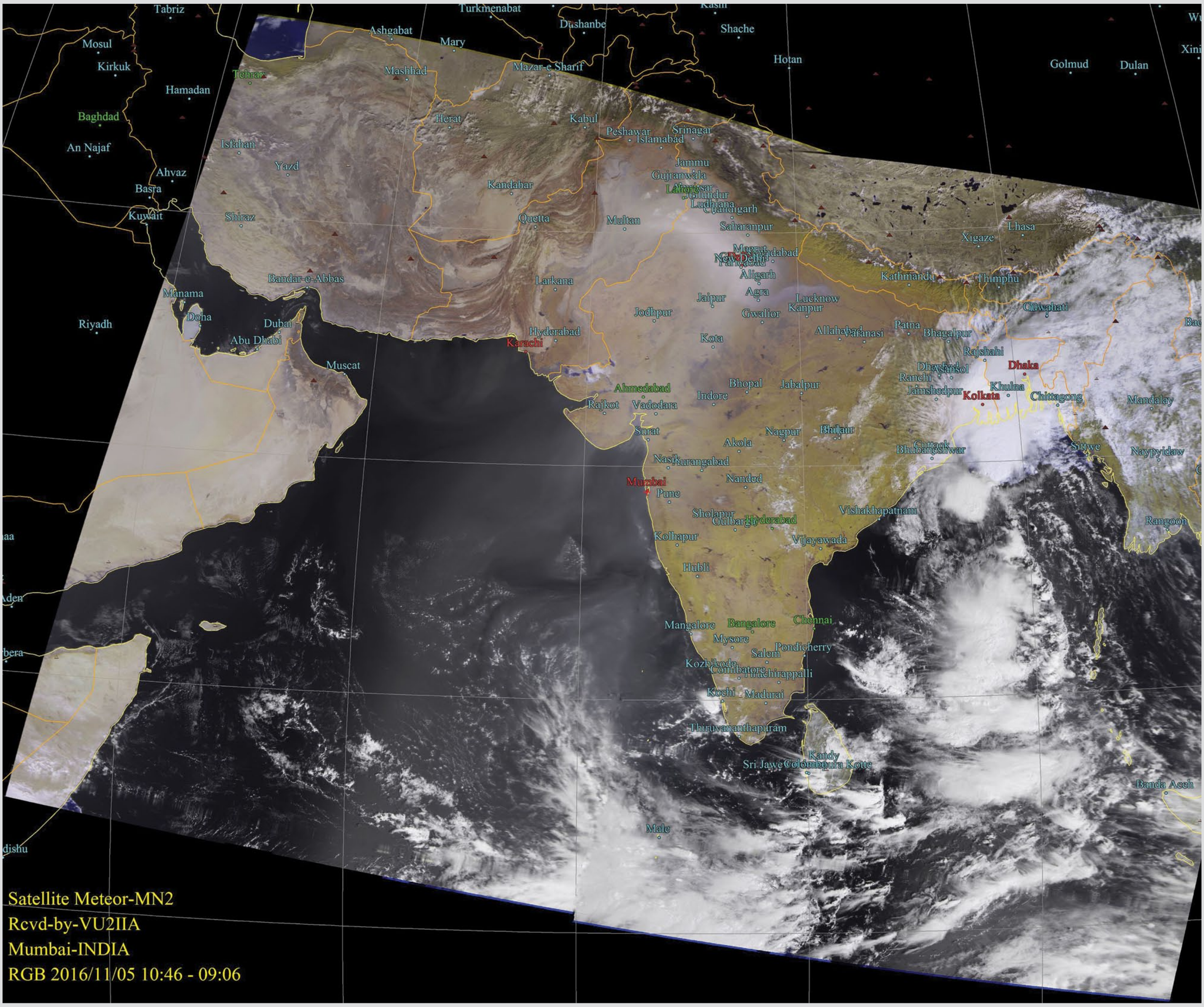
The IR images from the Japanese Himawai 8 satellite using the LUTLandSea-red processing tool in David Taylor's *MSG Data Manager* software, show the structure of these typhoons well.



This false-colour Metop-B image of Typhoon Haima was acquired just a few hours before the storm achieved landfall
Image © EUMETSAT 2016

Meteor GIS

Les Hamilton



This image was created by combining images from the 03:36 UT and 05:16 UT passes of Meteor M2

Recently, I was impressed by a Meteor M2 image posted on the GEO-Subscribers *YAHOO* group by Mahesh Vhatkar [1] from Mumbai. Not only was it a composite of two successive passes of the satellite, but the 'reset' bands had been cleverly disguised and the whole image provided with an overlay of country outlines and major cities. I found the concept intriguing, and felt that other GEO readers might like to follow his example: so I asked Mahesh how it was accomplished.

I was informed that both the composite M2 image and the map overlay were created by a free program called *MeteorGIS* which creates projected images from *LRPTDecoder*. This software was created by Christophe Marchand, and does everything once configured correctly. *MeteorGIS* also fills the reset and any other interference black lines on the Meteor images.

Norberto Felipe has a website, where you can download the *MeteorGIS* software and all the necessary information about how to configure it. Please visit his website at

http://h347.8k.com/meteor.htm

Finally, Mahesh carried out a little image enhancement in Photoshop.

Norberto provides comprehensive instructions for setting up and running Meteor GIS. For readers who have already set up a Meteor reception system, only one additional item is required, a copy of the *SGP4.dll* file, essential for georeferencing [2].

A Challenge

I don't plan to investigate MeteorGIS myself, but very much hope that some of our members will take up the challenge. It would be highly appreciated if articles for future issues of GEO Quarterly were forthcoming, hopefully highlighting imagery from all parts of the globe and explaining how members set up their reception systems and dealt with any problems encountered.

References

1 Meteor Images from India, GEOQ 44 (2015), p 14.
2 http://www.satsignal.eu/software/wxtrack.htm#SGP4

Massive and Mysterious Ice Fall in Tibet

NASA Earth Observatory

On July 17, 2016, a huge stream of ice and rock tumbled down a narrow valley in the Aru Range of Tibet. When the ice stopped moving, it had spread a 30-metre-thick pile of debris across 10 square kilometres. Nine people, 350 sheep, and 110 yaks in the remote village of Dungru were killed during the avalanche.

The massive debris field makes this one of the largest ice avalanches ever recorded. The only event of a comparable size was a 2002 avalanche from Kolka Glacier in the Caucasus, explained Andreas Kääb, a glaciologist at the University of Oslo.

A multispectral imager on the European Space Agency's **Sentinel-2** satellite captured an image of the debris field on July 21. The Operational Land Imager, a similar instrument on **Landsat 8**, acquired an image on June 24 that shows the same area prior to the avalanche.

The cause of the avalanche is unclear. 'This is new territory scientifically,' said Kääb. 'It is unknown why an entire glacier tongue would shear off like this. We would not have thought this was even possible before Kolka happened.'

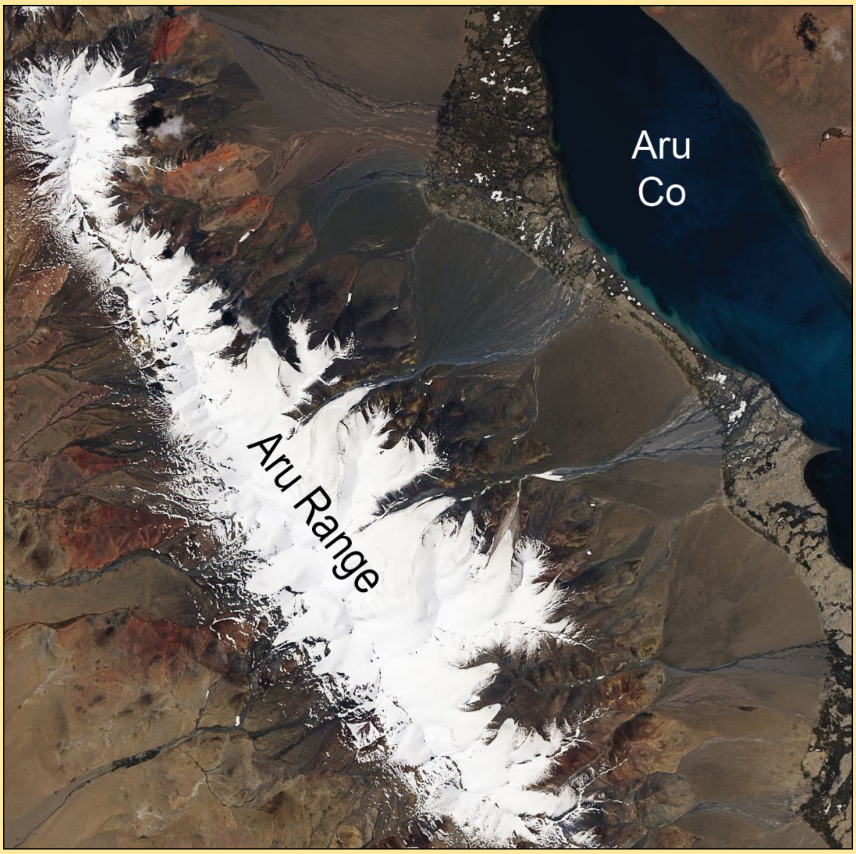
Kääb's preliminary analysis of satellite imagery indicates that the glacier showed signs of change weeks before the avalanche happened. Normally, such signs would be clues the glacier might be in the process of surging, but surging glaciers typically flow at a fairly slow rate rather than collapsing violently in an avalanche.

After inspecting the satellite imagery, University of Arizona glaciologist Jeffrey Kargel agreed that a surging glacier could not be the cause. 'The form is completely wrong,' he said. 'It must be a high-energy mass flow. Maybe liquid water lubrication at the base played some role.'

Tian Lide, a glaciologist at the Chinese Academy of Sciences, visited the site in August and described the avalanche as 'baffling' because the area where the ice collapse began is rather flat. 'We failed to reach the upper part of the glacier for safety reasons,' he stated in an email, 'but we do plan to go the upper part to see if we can find some more hints about what caused the disaster.'

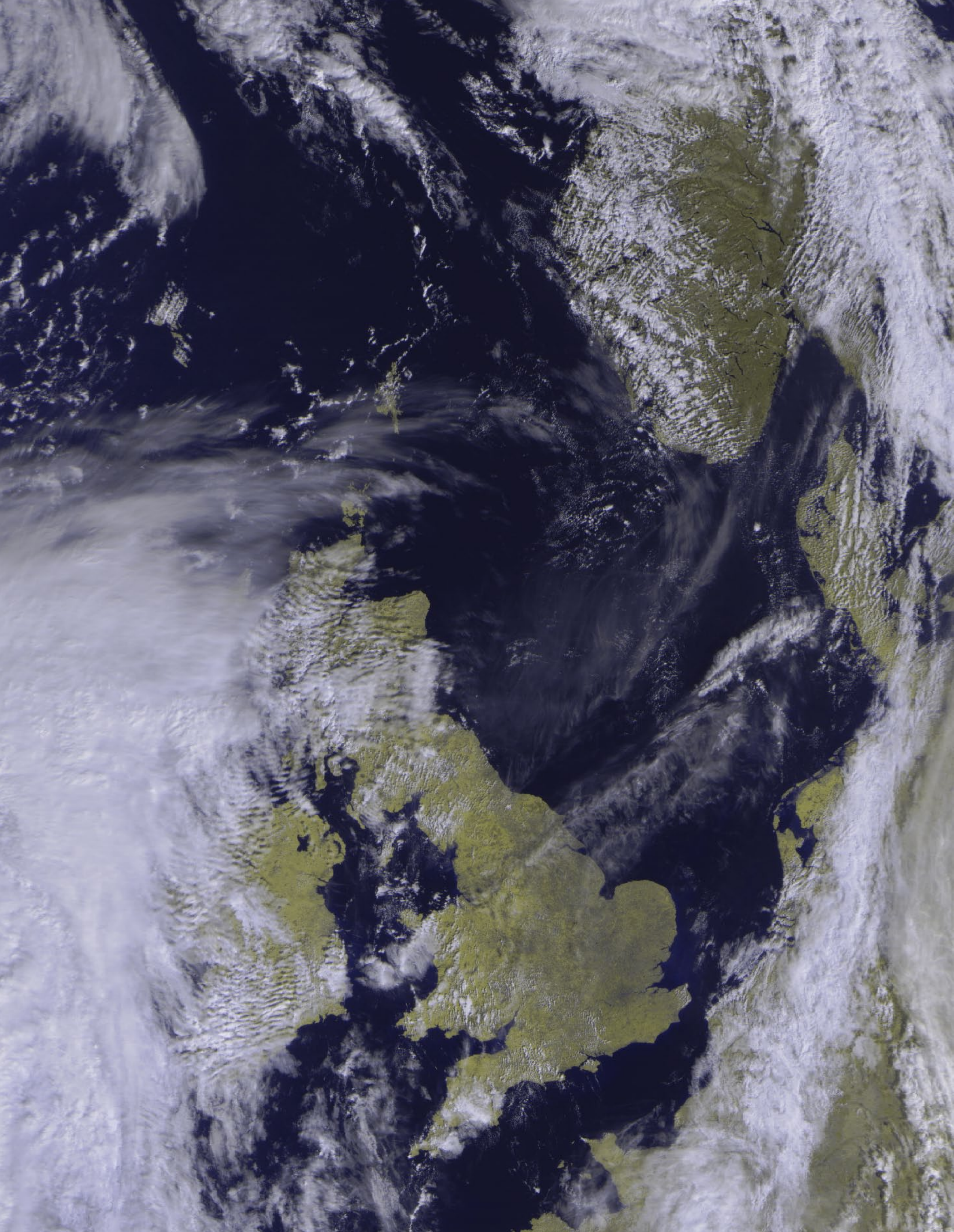
NASA Earth Observatory images by Joshua Stevens, using Landsat data from the US Geological Survey and Sentinel data from the European Space Agency.

Special thanks to Simon Gascoin for locating the images. Image interpretation assistance was by Andreas Kääb (University of Oslo), Tian Lide (Chinese Academy of Sciences), and Jeffrey Kargel (University of Arizona). Caption by Adam Voiland.



Landsat 8 image acquired on June 24, 2016, prior to the avalanche.

Sentinel 2 image acquired on July 21, 2016, showing the avalanche.



This was the scene captured from Meteor M2's 09:59 UT pass on September 11, 2016, as a spell of unseasonably warm weather swept up from southern Europe to provide an 'Indian Summer' to countries bordering the North Sea.

The First Weather Station in the Swiss Alps

Paul Geissmann HB3YGP
http://satellitenpaul.ch/

My receiving station lies just 15 kilometres from Säntis, at 2504 metres above sea level, the highest mountain in the Alpstein massif of northeastern Switzerland.

The 1879, the second International Meteorological Congress in Rome declared it necessary to build weather stations on suitable, and preferably freely accessible, mountain peaks. This request was acknowledged by Switzerland through the establishment of the Säntis station, whose upstream position north of the Alps proved to be particularly favourable. A special challenge was the creation of the necessary telegraph line.

Figure 1 - Säntis, photographed in April, 2015

It was in autumn 1882 that the Swiss Society for Natural Sciences established the first alpine weather station in Europe in a room in the Säntis Inn, a mountain guesthouse. Säntis, the northernmost peak of the Swiss Alps (figure 1), is ideal for forecasting approaching weather. Here weather coming from the west beats down, usually fiercely, because of the exposed position. The station was operated by John Beyer and Konrad Saxer, who initially stayed in the Säntis Inn, meeting up for their work only from spring till autumn.

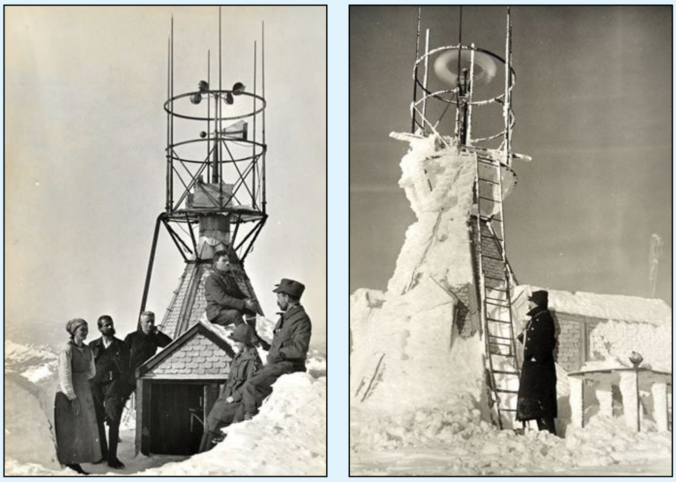


Figure 2 - Säntis weather station, pictured in 1915 (left) and 1920.

But in 1887, following a huge construction effort, an underground passageway blasted through the rocks to the summit was completed, enabling year-round monitoring activities. Figure 1 shows photographs of the weather station as it was over 100 years ago.

The exposed location of Säntis ensures extreme weather conditions: the average temperature is -1.9°C and precipitation is 2487 mm per year. The lowest ever recorded temperature was -32°C in January 1905 and the highest 20.8°C in July 1983. The highest daily total rainfall was 180 mm in June 1910. The highest rainfall in one hour was the 81.9 mm measured in July 1991. Indeed, Säntis is the wettest place in Switzerland.

Between April 21-23, 1999, a blizzard deposited 816 cm of snow on the mountain's northern snowfield, the greatest depth ever measured in Switzerland. And on December 26 the same year, during cyclonic storm *Lothar,* a record wind speed of 230 km/h was measured on the summit. Snow can be expected in all months of the year on Säntis, even during the summer: fully a metre fell during August 1995. Säntis is extremely prone to lightning strikes and can experience as many as 400 annually.

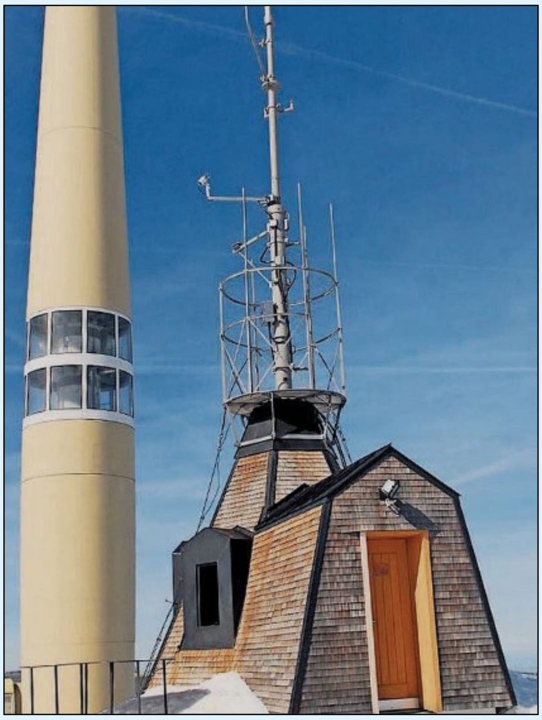


Figure 3 - The original meteorological station stands beside the present-day transmitting tower

In the beautiful Appenzell region, just nine kilometres from Säntis, stands *MeteoGroup* Switzerland's 'Weather Factory' (figure 4). This, a branch of Jörg Kachelmann's Meteomedia AG Weather Service, currently employs around 20 people and is a branch of the largest private European weather information provider.

Weather forecasts for media (German broadcasting service, ARD, newspapers and radio) are created here (figure 5, 6), but particularly special forecasts for the transport sector in

Figure 4 - Dish antennas at the Weather Factory

Figure 5 - The Entrance Foyer at Appenzell

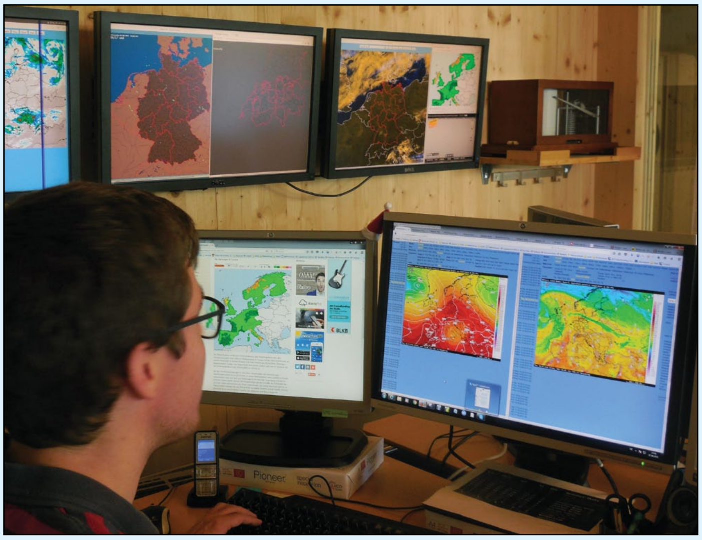


Figure 6 - The workplace at Meteo Group in Appenzell

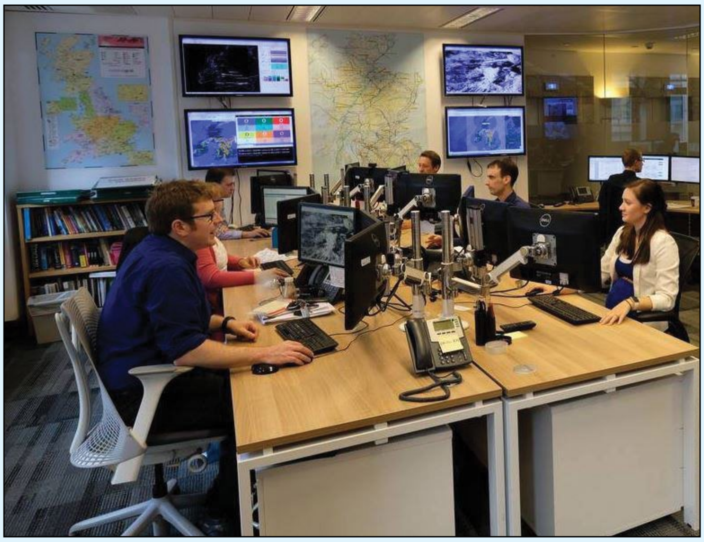


Figure 7 - The London office of MeteoGroup, who will replace the Met Office as the BBC's official weather provider in 2017.

the Alpine region: about the railways, winter maintenance forecasts for highways, cantons, cities and municipalities as well as for the airports of Zurich, Milan and Bergamo.

For 10 years, the focus has also been on producing accurate weather warnings from their website at

www.meteocentrale.ch

MeteoGroup Switzerland also operates a private automatic weather monitoring network that, within Switzerland, currently comprises about 380 stations. This bypasses the professional meteorologists in the 'weather-room' to provide highly accurate local forecasts.

In the UK, *MeteoGroup* has been chosen as the company to replace the Met Office as the BBC's weather forecaster from spring 2017 (figure 7).

My Own Satellite Activities

I first started receiving NOAA images from space with the simple receivers that were available 40 years ago, but was later lucky to obtain some discarded equipment from Kloten Airport. This included a Muirhead 'Mufax' chart recorder and expensive shortwave and longwave receivers. Finally, I received a satellite receiver for the reception of the Meteor and NOAA series.

With the Mufax chart recorder I could then display Meteor and NOAA images on paper, just like the German Weather Service. Figure 8, acquired in 1980, is most likely from the Soviet Meteor 1-30 satellite, launched early that year, and shows the Alps and Italy with, at far right, the numerical telemetry data typical of that satellite. Over the years I obtained images from a variety of satellites, including the Meteor-2 and Meteor-3 series, Okean and SICH. In those days the PC was still in its infancy, so these images could only be recorded on paper.

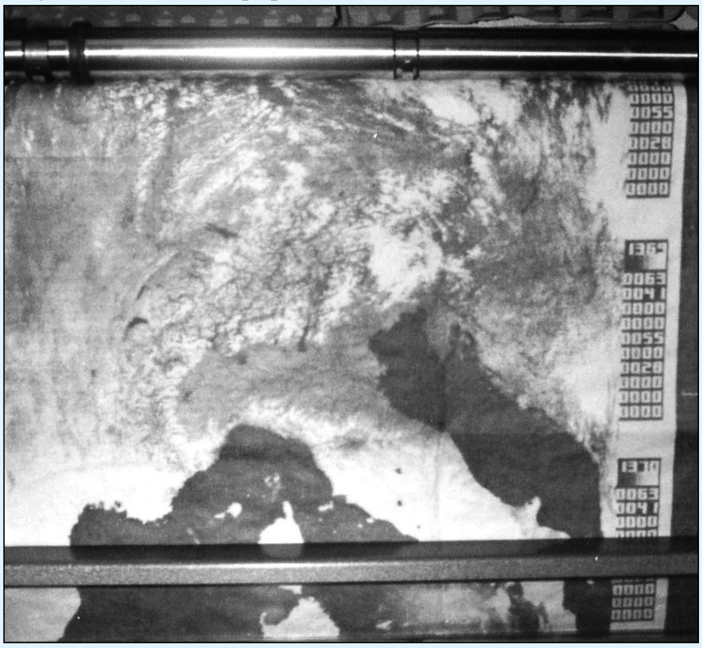


Figure 8 - A 1980 'Mufax' image, probably from the Russian satellite Meteor 1-30.

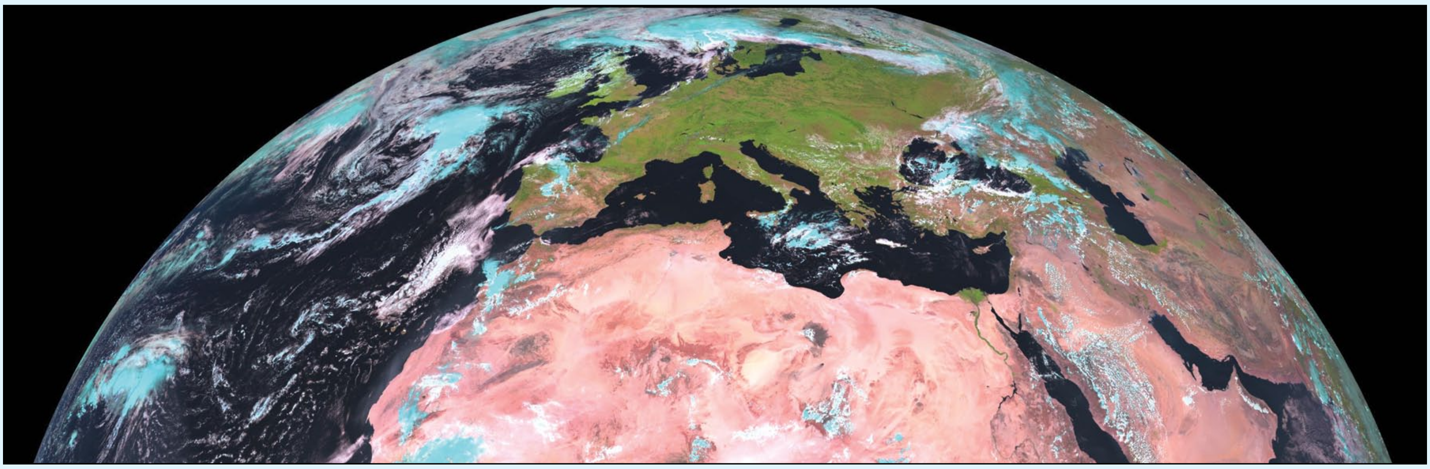


Figure 9 - The August 26, 2016 noon image from Meteosat

Figure 10
The Author's first homebrew Dish Antenna

I also wished to receive Meteosat's geostationary images on the 1691 MHz frequency, but in those days, you could not easily buy a parabolic dish antenna; as I could not afford one, I built a dish myself—difficult, and not beautiful—but it worked. For my first attempt I started with a fibreglass skylight dome and glued aluminium foil inside it. This dish actually worked but the signal was rather weak. For my second attempt, I constructed a parabolic template out of wood and triangular, perforated aluminium plates, the latter being riveted together and placed inside it. This dish worked really well but storm *Lothar* tore the dish from its mount. Fortunately, an insurance payment for the storm damage to my property allowed me at last to purchase a proper 1.7 m dish.

At that time it was almost a sensation that amateurs could receive such images. But thanks to today's software and hardware, amateurs are able to compete with the professionals by receiving super, high quality images from space.

Nowadays, in addition to the NOAA satellites (figure 12), I run a EUMETCast system which brings me regular images of our entire hemisphere (figure 9).

Figure 11 - The author, pictured cooling off outside his home station during a heatwave on July 5, 2015.

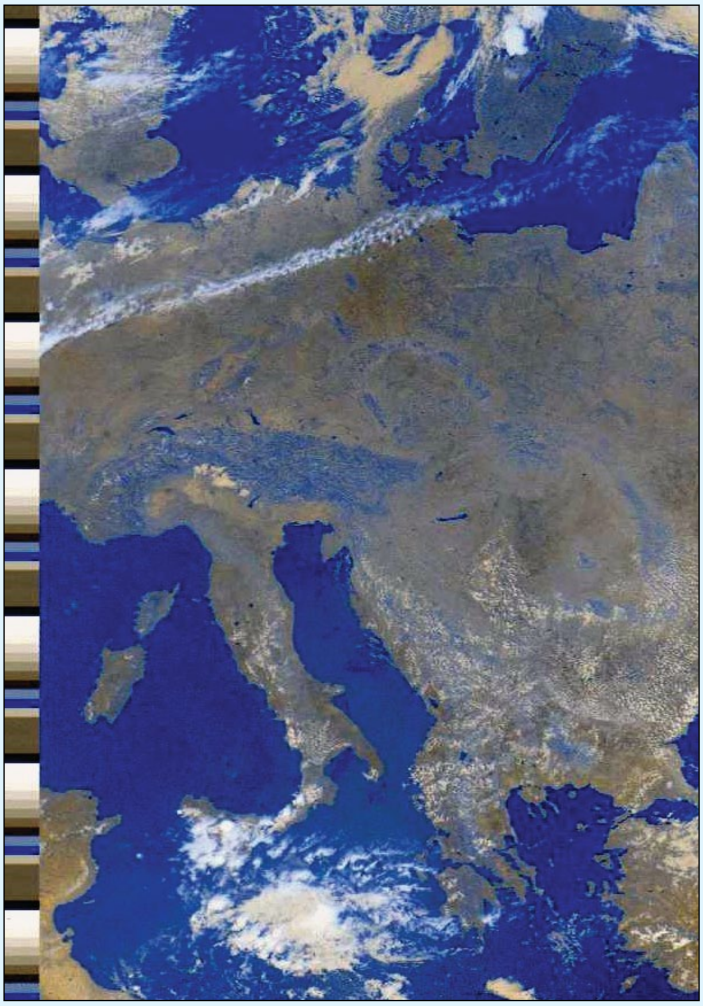
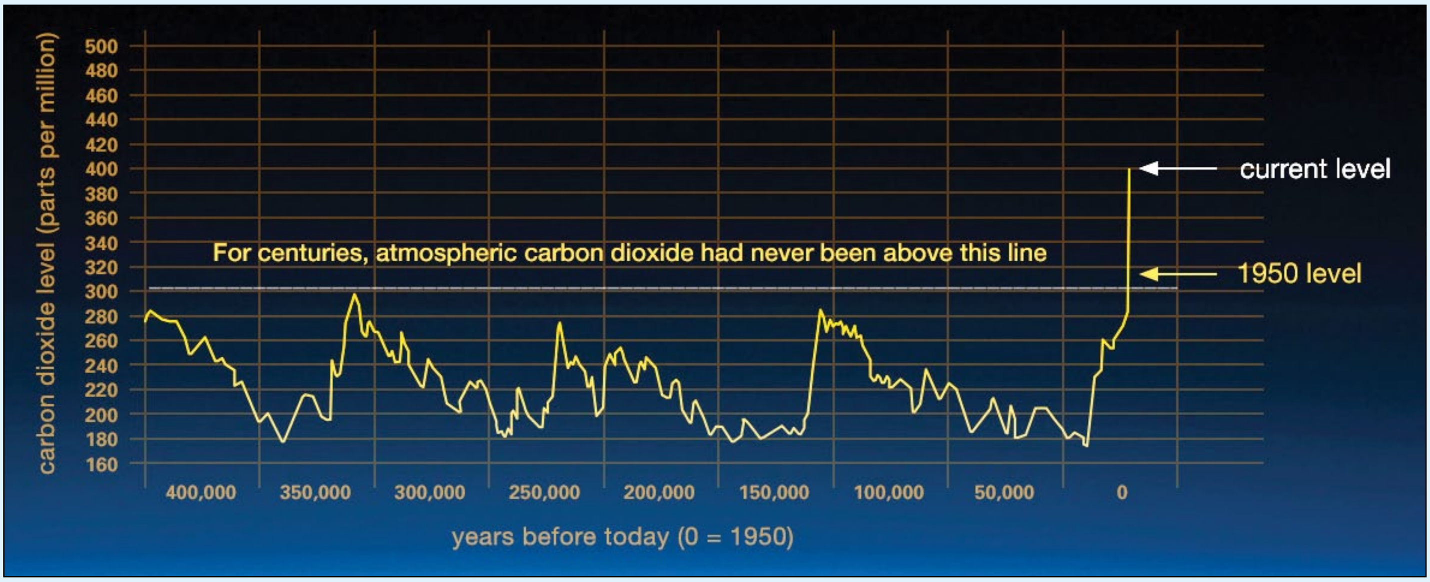


Figure 12 - Detail from the 12:25 UT NOAA-19 pass on August 26, 2016.

Climate Change: How do we know?

NASA



Atmospheric carbon dioxide levels during the past 400 000 years.

Credit: Vostok ice core data / J.R. Petit et al.; NOAA Mauna Loa CO_2 record.

This graph, based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements, provides evidence that atmospheric CO_2 has increased since the Industrial Revolution.

The Earth's climate has changed throughout history. There have been seven cycles of glacial advance and retreat during the past 650,000 years alone. The abrupt end of the last ice age—about 7,000 years ago—marked the beginning of the modern climate era and of human civilisation. Most of these climate changes can be attributed to very small variations in Earth's orbit that change the quantity of solar energy our planet receives.

The current warming trend is of particular significance because most of it has very likely been human-induced and it is currently proceeding at a rate that is unprecedented in the past 1,300 years.

Earth-orbiting satellites and other technological advances have enabled scientists to see the big picture, collecting many different types of information about our planet and its climate on a global scale. This body of data, collected over many years, reveals the signals of a changing climate.

The heat-trapping nature of carbon dioxide and other gases was demonstrated in the mid 19th century [2]. Their ability to affect the transfer of infrared energy through the atmosphere is the scientific basis of many instruments flown by NASA satellites. There is no question that increased levels of greenhouse gases must cause the Earth to warm in response.

Ice cores drawn from Greenland, Antarctica and tropical mountain glaciers show that the Earth's climate does respond to changes in greenhouse gas levels. They also show that, in the past, large changes in climate have happened very quickly, geologically-speaking: in tens of years, rather than millions or even thousands.

The evidence for rapid climate change is compelling. Indeed, the *Intergovernmental Panel on Climate Change* [1] has stated that: 'Scientific evidence for warming of the climate system is unequivocal.'

Sea Level Rise

Global sea level rose about 17 centimetres during the 20th century. The rate in the past decade, however, is nearly double that of the last century

Global Temperature Rise

All three major global surface temperature reconstructions show that Earth has warmed since 1880. Most of this warming has occurred since the 1970s, with the twenty warmest years having occurred since 1981 and the ten warmest of these occurring during the past twelve years. Even though the 2000s witnessed a solar output decline resulting in an unusually deep solar minimum in 2007-2009, surface temperatures continued to increase.

Warming Oceans

The oceans have absorbed much of this increased heat, with the top 700 metres of oceanic water showing warming of 0.168 degrees Celsius since 1969.

Shrinking Ice Sheets

The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's *Gravity Recovery and Climate Experiment* [3] show that Greenland lost between 150 and 250 cubic kilometres of ice per year between 2002 and 2006, while Antarctica lost about 152 cubic kilometres of ice between 2002 and 2005.

Declining Arctic Sea Ice

Both the extent and thickness of Arctic sea ice have declined rapidly over the past several decades.

Glacial Retreat

Glaciers are retreating almost everywhere around the world: in the Alps, Himalayas, Andes, Rockies, Alaska and Africa.

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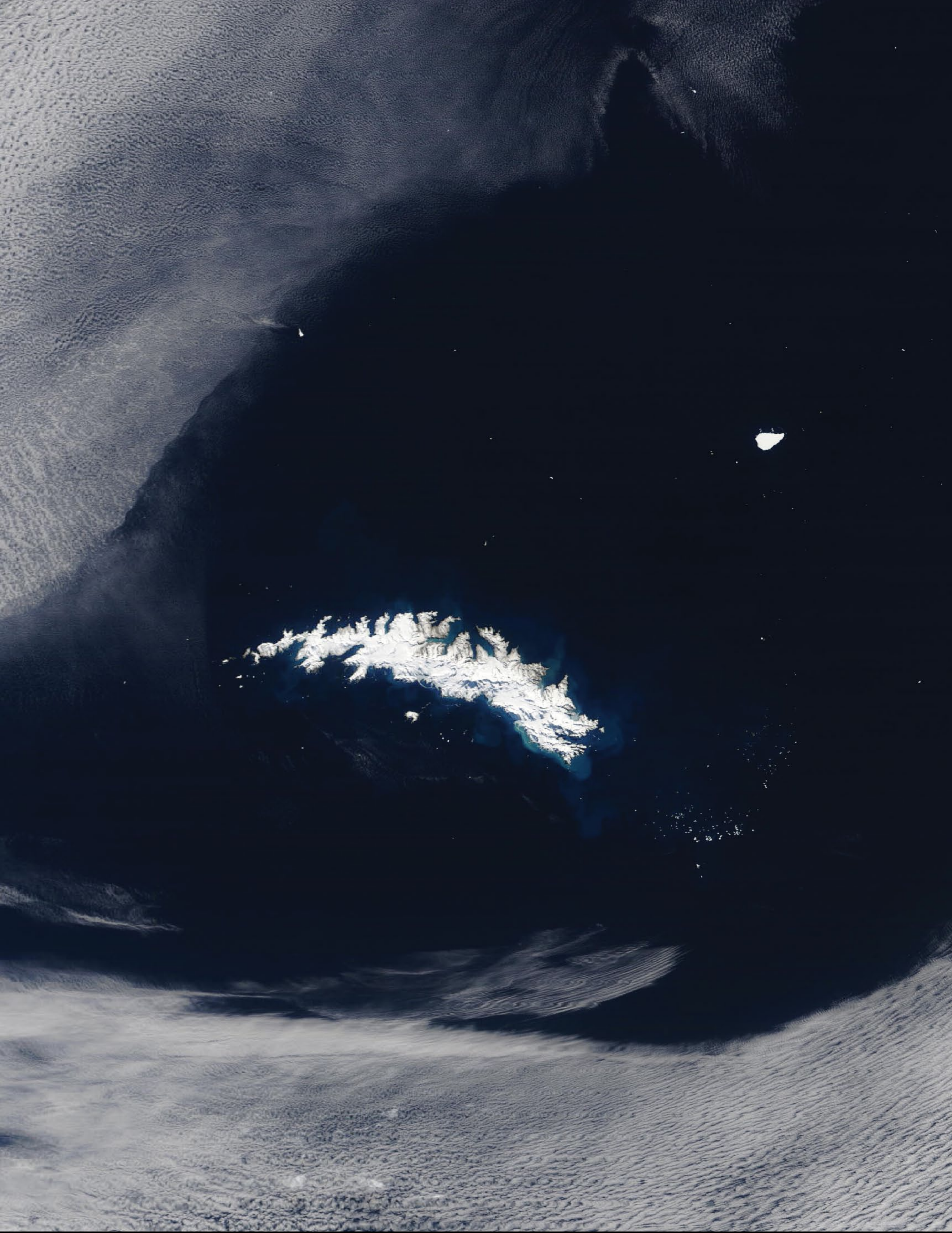
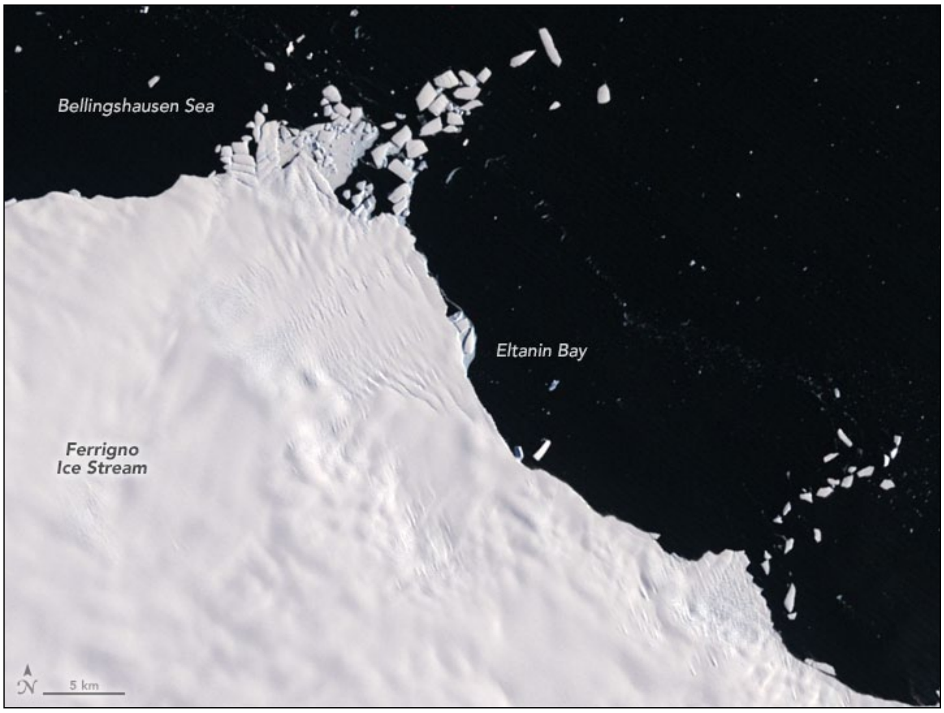


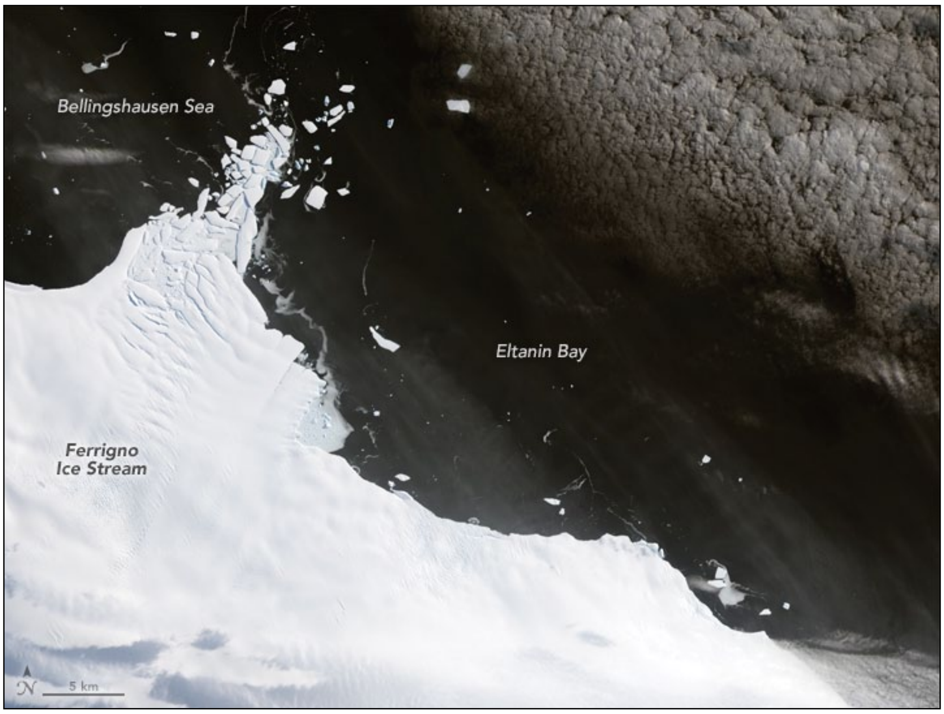
The MODIS instrument aboard NASA's Terra satellite images this scene showing a large iceberg north east of South Georgia on September 26, 2016.
Image: LANCE Rapid Response/NASA/GSFC

Pervasive Ice Retreat in West Antarctica

NASA Earth Observatory

Along the Bellingshausen Sea coast of West Antarctica, ice has been retreating inland being lost to the sea. Scientists knew this, but they lacked a full picture of the scale. Now a team of researchers has compiled a *Landsat*-based data-set and found that such losses have been going on for at least the past four decades—and along the vast majority of this coast.





"We knew that ice had been retreating from this region recently," claimed Frazer Christie, a doctoral candidate at the University of Edinburgh and a co-author of the study. "Now, thanks to a wealth of freely available satellite data, we know this has been occurring pervasively along the coastline for almost half a century."

The Bellingshausen Sea—named for the Russian Admiral who found the continent in 1820—lies to the west of the Antarctic Peninsula. Examining *Landsat* data collected between 1975 and 2015, the researchers mapped the approximate locations of 'grounding lines' in the ice along the Bellingshausen coast. These lines mark the intersection where glacial ice flowing from the continent is connected, or grounded, to the sea floor. Any ice past the grounding line usually floats on the sea as an ice shelf. When ice is lost to the sea, the grounding line retreats. Meanwhile, the ice loss contributes to global sea level rise.

Christie and colleagues used *Landsat* data to locate 'inflection points' on the surface of the ice that indicate the approximate location of grounding lines below. An inflection point—which can be tricky to detect by an untrained eye—is defined as the final location where the slope of the ice dramatically changes before flattening out into an ice shelf on meeting the sea. The team combined its *Landsat* projections of inflection points with radar data from the European Space Agency's ERS-1, ERS-2 and CryoSat-2 satellites. They found that the majority of the coastline along the Bellinghausen Sea had experienced some grounding line retreat over the past four decades. The findings were published in *Geophysical Research Letters*.

The widespread retreat has most likely been caused by warmer ocean water licking at the undersides of the floating ice near the grounding line—or as the authors write: 'an ingress of relatively warm circumpolar deep water.'

The images above show an area near Eltanin Bay, where the majority of the grounding line is found at the seaward front of the ice. The top image was acquired by Landsat-2's *Multispectral Scanner* on February 18, 1975; the second image was acquired by Landsat-8's *Operational Land Imager* on March 2, 2015. The ice loss is most pronounced along the Ferrigno Ice Stream, which was named for Jane Ferrigno, a US Geological Survey scientist who used satellite data to map Antarctica.

This study provides important context for understanding the causes of ice retreat throughout Antarctica as a whole, and it is now known that West Antarctica has been changing for many decades. The next challenge is to ascertain the key ice, ocean, and atmospheric factors responsible for such ice losses.

NASA Earth Observatory images by Jesse Allen, using Landsat data from the US Geological Survey. Caption by Laura Rocchio, Landsat Communication and Public Engagement Team.

Seeing Equinoxes and Solstices from Space

NASA Earth Observatory

One of the most frequently misunderstood concepts in science is the reason for Earth's seasons, so here's a space-based view of what's going on.

Around 6 am local time each day, the Sun, Earth, and any geosynchronous satellite lie at the corners of a right angled triangle, affording a nadir (straight down) view of the terminator—the edge between the shadows of nightfall and the sunlight of dusk and dawn. The position of this line between night and day varies with the seasons, which means different lengths of days and differing amounts of warming sunshine. (The line is actually a curve, but satellite images only show it in two-dimensions.)

The *Spinning Enhanced Visible and Infrared Imager* (SEVIRI) on EUMETSAT's **Meteosat-9** captured these four views of Earth from geosynchronous orbit. The images show how sunlight fell on the Earth on December 21, 2010 (upper left), and March 20 (upper right), June 21 (lower left), and September 20, 2011 (lower right). Each image was taken at 6:12 am local time.

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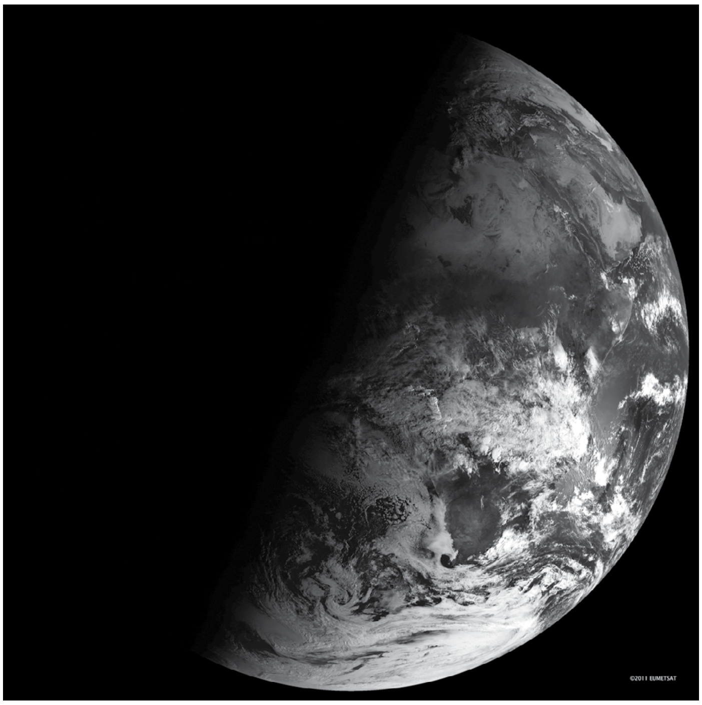
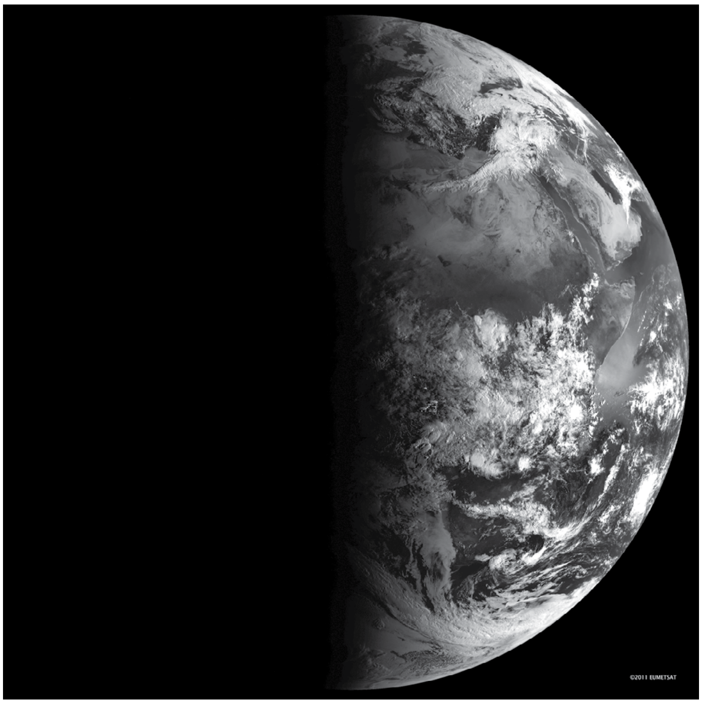
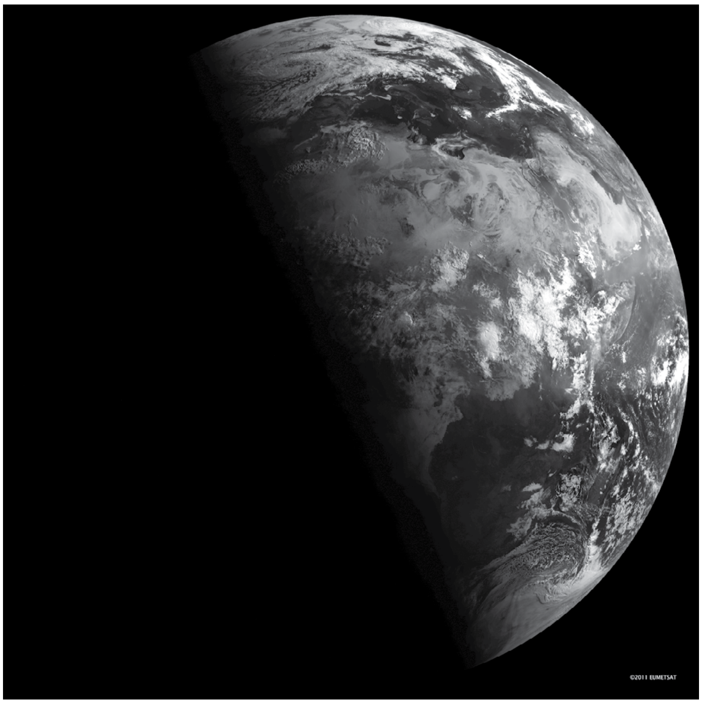


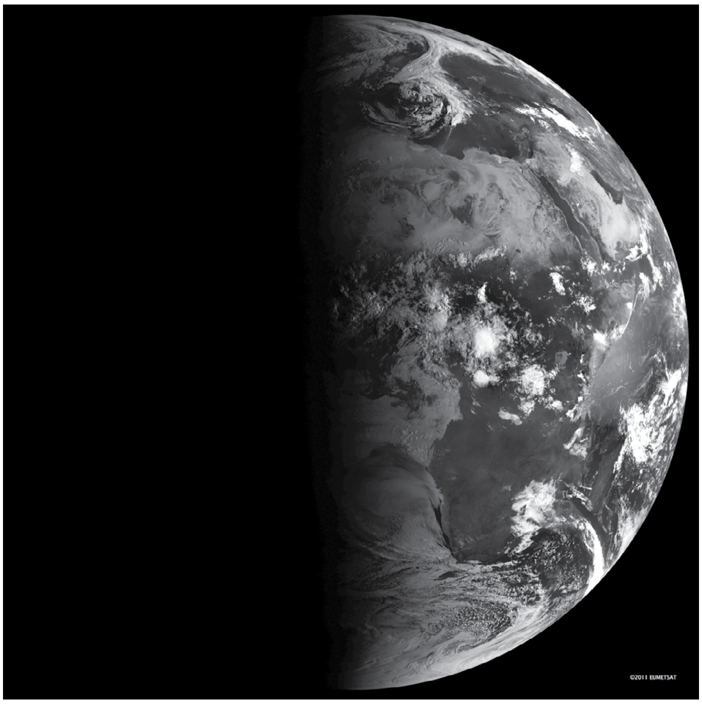
December 21, 2010



March 20, 2011

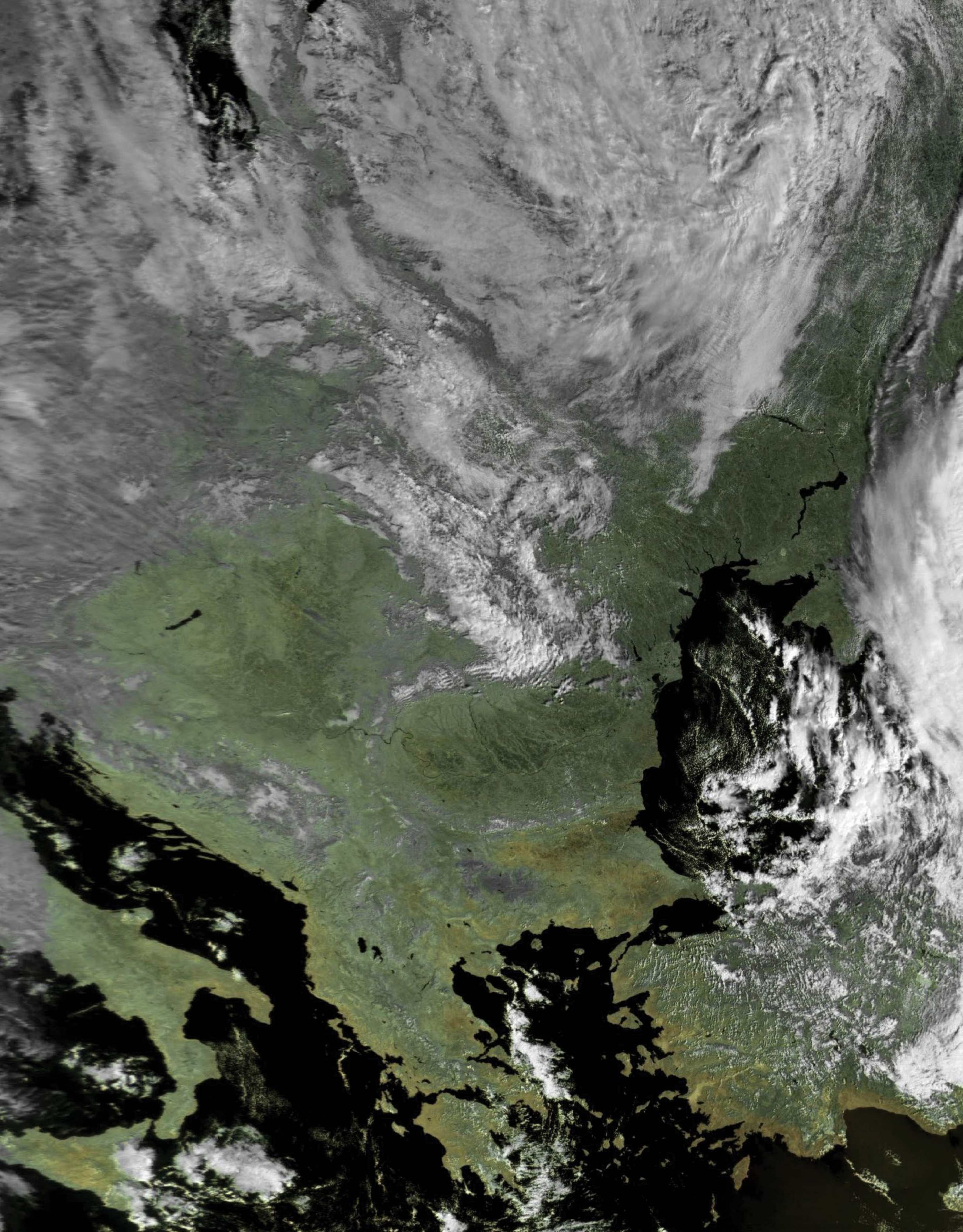


June 21, 2011



September 20, 2011

Credit: NASA images and animation by Robert Simmon, using data ©2010 EUMETSAT. Caption by Mike Carlowic



This is a section from a Meteor M2 LRPT image acquired from the 07:46 UT pass on September 23, 2016 by Enrico Gobbetti.

An Introduction to Receiving APT

from the NOAA Polar Orbiting Environmental Satellites

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Earth imaging satellites have played a key role in meteorology for over half a century. The very first images of Earth from a satellite were obtained on August 14, 1959 by the U.S. satellite *Explorer 6*. These images were very crude by today's standards. The first weather satellite considered to be a success was *TIROS-1* (Television Infrared Observation Satellite). This was launched on April 1, 1960, and was operational for 78 days. In total, ten TIROS satellites were launched between 1960 and 1965. These were succeeded by the *ESSA* (Environmental Science Services Administration) series of satellites, nine of which were launched between 1966 and 1969, and finally by the *NOAA* (National Oceanic and Atmospheric Administration) satellites, nineteen of which were launched between 1970 and 2009. Of these nineteen, three are still in operation, and these are the main focus of this article.

Types of Satellite Orbit

There are four different basic types of satellite orbit around the Earth classified according to altitude. Satellites in low Earth orbit (LEO) typically have an altitude of between one hundred miles and one thousand miles. Their orbital periods range between roughly 90 and 120 minutes, and increase with increasing altitude. The TIROS satellites and their successors have all been LEO satellites. Satellites in medium Earth orbit (MEO) typically have an altitude of between one thousand miles and twenty-two thousand miles. Their orbital periods range between roughly two hours and twenty-four hours. Satellites in high Earth orbit (HEO) have an altitude greater than twenty-two thousand miles, and orbital periods greater than one day. At the boundary between MEO and HEO, at an altitude of 22,236 miles, the orbital period is precisely one day. Since the orbit of the satellite synchronises precisely with the rotation of the Earth there is no apparent movement of the satellite. Such an orbit is called a geostationary orbit.

Each of these types or orbit has advantages and disadvantages. Geostationary orbits are useful because once the antenna, typically a dish, has been accurately aimed at the satellite, no further adjustment is required. Satellites carrying domestic television services are in geostationary orbits. Signals from geostationary orbit and HEO are relatively weak, and a high-gain antenna is required in order to achieve reliable reception. The images from a given geostationary satellite only cover roughly one third of the Earth's surface, and the signals from such a satellite may only be received from a similarly limited proportion of the Earth's surface. Low Earth orbits are useful because the signals from these satellites are relatively strong. Even if the output power of the transmitter is only a few watts, reception is possible with a quite modest antenna and receiver. As the position of the satellite is always changing relative to the ground, it may serve most of the Earth's surface. From the point of view of Earth imaging, images from LEO satellites have a much greater resolution than those from higher altitude satellites. For this reason, many weather satellites are in low Earth orbits.

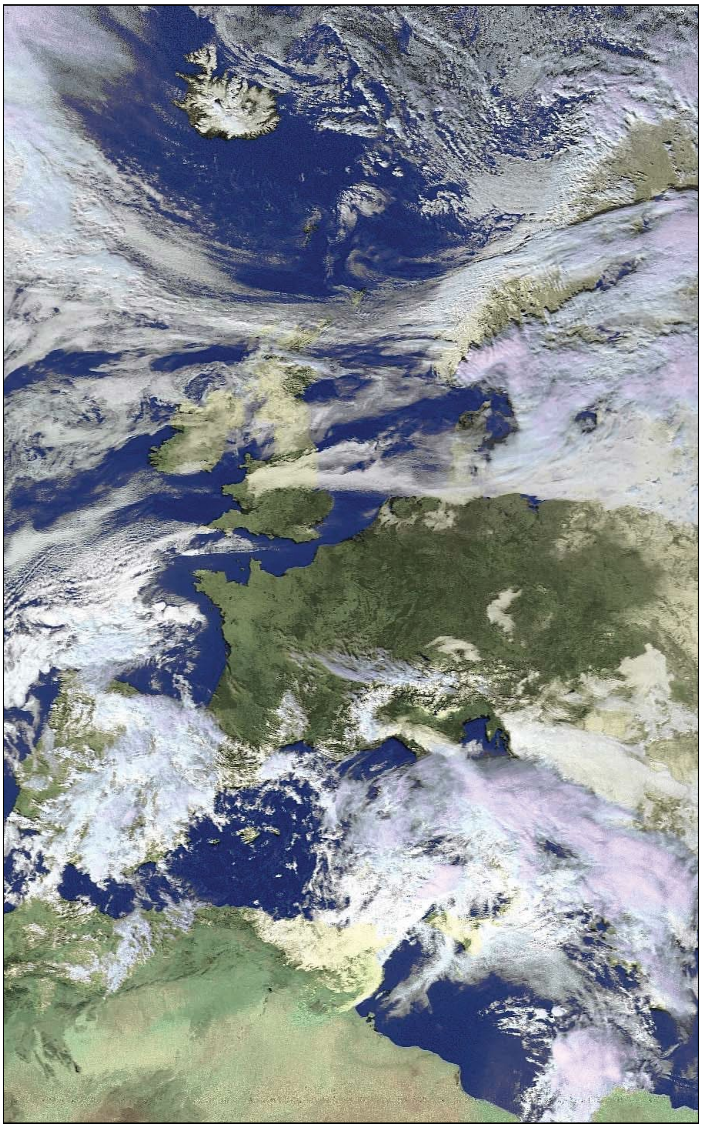

Figure 1 - typical HVCT enhancement of an APT signal

Weather Satellites

In Europe, EUMETSAT (European Organisation for the Exploitation of Meteorological Satellites) operate the *Meteosat* series of satellites in geostationary orbit, and the LEO satellites *Metop-A* and *Metop-B*. It was originally intended that the *Metop* satellites would transmit LRPT (low rate picture transmission) on 137 MHz, but this was abandoned due to interference with other instrumentation. *Meteosat-9* and -10 are located over Africa at longitude 9.5 degrees east and 0 degrees respectively, and provide imaging of Africa and Europe. At the time of writing, *Meteosat-8* is in the process of being relocated from over

Africa to over the Indian Ocean, where it will take over from the decommissioned *Meteosat-7*. Near real-time reduced resolution imagery from the *Meteosat* and *Metop* satellites is available via the EUMETSAT website. Images from the Meteosat and *Metop* satellites are relayed at full resolution via a system called EUMETCast. The origin of this system was the failure of the 1.7 GHz power amplifier on *Meteosat-8*. This failure made direct reception from the satellite unfeasible without a very large dish antenna. Instead, images were relayed via a geostationary domestic television satellite.

Today EUMETCast is relayed via Eutelsat-10A on a frequency of 11263 MHz in the Ku-band, with a footprint covering the UK and continental Europe. EUMETCast uses a format called DVB-S2 (Digital Video Broadcasting – Satellite, second generation). Reception requires only an 85 cm dish, and a DVB-S2 receiver, both of which are widely available at affordable prices. The data is encrypted, and to obtain the decryption key one needs a licence issued by EUMETSAT to receive EUMETCast products. Happily, these are available at no charge to amateur weather satellite enthusiasts.

Coverage of North and South America is provided by the *GOES* (Geostationary Operational Environmental Satellites) operated by the National Environmental Satellite, Data, and Information Service (NESDIS). *GOES-13* (also known as *GOES-East*) is positioned at longitude 75°W, whilst *GOES-15* (also known as *GOES-West*) is positioned at longitude 135°W. *GOES* imagery may be received direct from the satellite on 1.7 GHz but, following the example set by EUMETCast, is also relayed via GEONETCast using the television satellite *New Skies NSS-806* in the C-band. On November 19, 2016, *GOES-R* was successfully launched. This new geostationary satellite has capabilities significantly beyond the previous satellites in the GOES series, including three times more spectral information, four times greater spatial resolution, and real-time mapping of lightning activity. The satellite will be renamed as *GOES-16* once it has reached its final designated orbit in December 2016.

NOAA Polar Orbiting Environmental Satellites

In this article, we are concerned with the NOAA Polar Orbiting Environmental Satellites (POES), which are in a very specific type of LEO. These orbit at a mean altitude of around 525 miles and have an orbital period of 104 minutes. The orbits are sun synchronous, meaning that the plane in which each satellite orbits remains fixed relative to the position of the sun. The result of this is that each pass of the satellite takes place at roughly the same local time relative to the longitude of the pass. There are currently three Polar Orbiting Environmental Satellites in operation, which were launched from Vandenberg Air Force Base in California on the following dates:

NOAA-15 - Launched May 13, 1998
NOAA-18 - Launched May 20, 2005
NOAA-19 - Launched February 6, 2009

Each POES satellite carries an Advanced Very High Resolution Radiometer (AVHRR), which is in effect the satellite's camera. The AVHRR has sensors that measure electromagnetic radiation reflected from the Earth in six spectral bands, or 'channels', as described in Table 1.

Data from two channels of the AVHRR is transmitted using an analogue system known as automatic picture transmission (APT). The two channels that are used varies. Whilst the satellite is in sunlight, NOAA-15 and NOAA-19 usually carry channels 2 and 4, and NOAA-18 usually carries channels 1 and 4. Whilst in darkness all three satellites carry channels 3 and 4. The data is transmitted as a horizontal line-scan at a rate of two lines per second. Each line is 2080 pixels long, and hence the data rate is 4160 baud. The raw data received may be decoded using suitable software, and appears as monochrome images from the two channels side by side. The satellites also provide high-resolution picture transmission (HRPT) in the 1.7 GHz band. The HRPT service carries all of the channels from the AVHRR. Reception of HRPT requires a steerable antenna and is beyond the scope of this article. The frequencies currently in use (as of November 2016) for APT and HRPT from NOAA-15, 18 and 19 are shown in Table 2.

Of these three, NOAA-19 consistently gives the best images. From any given location, the APT transmission

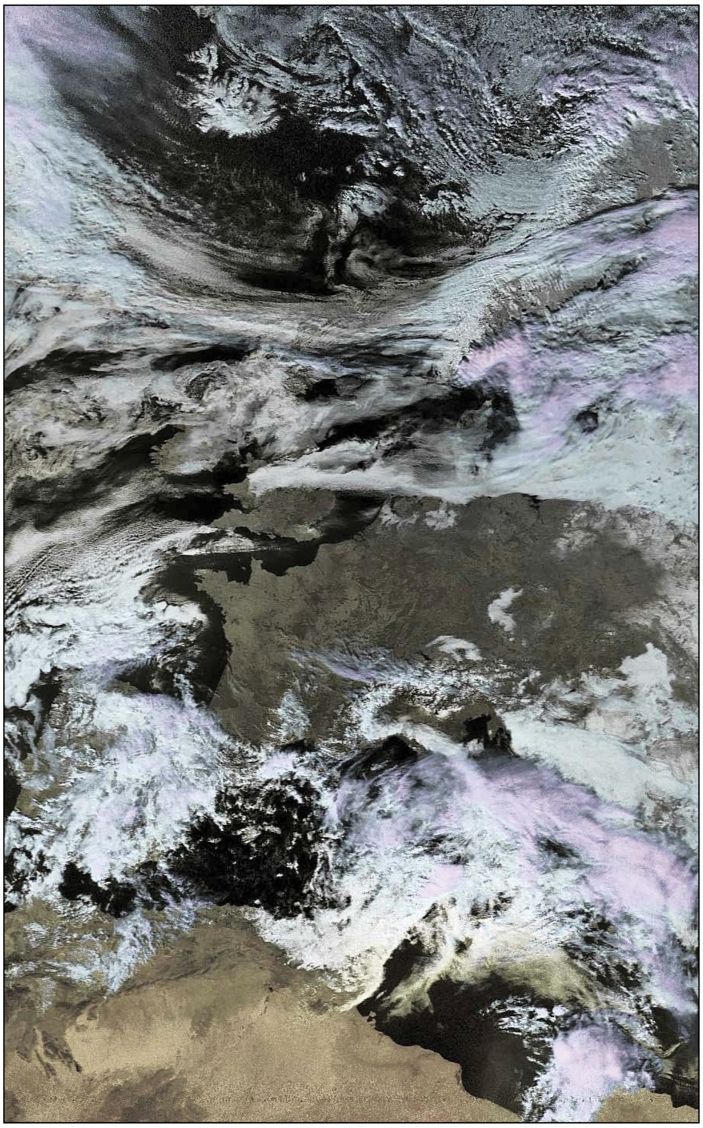

Figure 2 - HVC Enhancement of an APT Signal

Channel	Wavelength (μm)	Description	Typical Use
1	0.58 - 0.68	Visible	Daytime cloud and surface mapping
2	0.725 - 1.00	Visible	Land-water boundaries
3A	1.58 - 1.64		Snow and ice detection
3B	3.55 - 3.93		Night cloud mapping
4	10.30 - 11.30	Infrared	Night cloud mapping
5	11.50 - 12.50	Infrared	Sea surface temperature

Table 1 - NOAA AVHRR Sensors

Satellite	APT	HRPT
NOAA 15	137.6200 MHz	1702.5 MHz
NOAA 18	137.9125 MHz	1707.0 MHz
NOAA 19	137.1000 MHz	1698.0 MHz

Table 2 - The NOAA AVHRR Frequencies

from each satellite may be received for three passes each day during the daytime and a further three passes during the night.

Hardware

Reception of APT from the NOAA satellites requires a suitable receiver and antenna. A general coverage receiver or scanner covering the 137 MHz band will give fair results but a purpose-built receiver will perform much better. Ideally, the receiver should feature automatic frequency control, enabling it to compensate for the shift in frequency during the satellite pass that arises from the Doppler effect. Also, the bandwidth of APT is around 30 kHz, which is a little too wide for most scanners, resulting in clipping of the signal. The author uses the R2ZX receiver (figures 3,4) which was the standard receiver recommended and sold by GEO for several years. Unfortunately, this receiver is no longer being manufactured, but the APT-06 receiver of similar specification is available from WRAASE Electronic in Germany.

Figure 3 - The R2ZX receiver for APT on 137 MHz

Running software to process data from the satellites requires only a PC or laptop of modest specification with a sound card. The audio signal from the receiver is fed into the microphone input socket on the laptop. The audio volume of the receiver and the gain of the microphone preamp need to be carefully set to maximise signal whilst avoiding distortion. The author uses a ten year old laptop running Windows XP as a machine dedicated to running weather satellite software and weather station software. As an alternative to the receivers mentioned above, reception of APT may be achieved using a software defined radio dongle, such as the Newsky RTL2832U/R820T2, with suitable software.

The APT signals are transmitted with right-hand circular polarisation. Whilst fair reception can be obtained from a VHF antenna such as a discone intended for use with scanners, the results are much improved if an antenna designed for circular polarisation at 137 MHz is used. The author uses a crossed dipole (turnstile) antenna mounted on a short mast on the chimney stack, and this gives excellent results. An alternative to the crossed dipole is the quadrifilar helix (QFH) antenna, but these are considerably more expensive. As with any antenna, good quality coaxial cable such as RG58 should be used to connect the antenna to the receiver.

Software

There are several programs available for decoding APT data and processing this to give informative and aesthetically pleasing images. One of the most popular is *WXtoImg* ('Weather to Image'), and this is the program used by the author. Figure 5 is a screen capture of WXtoImg in the process of recording a pass of NOAA-19. The software combines the two AVHRR images to give a single,

Figure 4 - FT-2000, Pakratt PK-232 tnc, R2ZX receiver and Davis Vantage VUE weather console

artificially coloured image. The basic freeware version of WXtoImg features five different enhancement options for producing an image. HVC is the most basic, and gives a coloured tint to clouds which varies according to their temperature. HVCT and MSA (multi spectral analysis) both make use of a map overlay to distinguish land from sea, allowing a more naturally coloured image to be produced, with blue for sea and green/brown for land. MCIR (map coloured infrared) is used to produce colour images whilst the satellite is in darkness. The 'thermal' option gives an image which is artificially coloured according to temperature. Figures 1,2,6,7 and 8 show examples of each of these processing options.

The Standard and Professional editions of WXtoImg provide several further enhancement options, including enhancements which show precipitation. There are many other additional features, including the facility to produce composite images from two or more consecutive passes of a satellite. Upgrade to the Standard or Professional editions requires an upgrade key, which used to be available for a one-off fee. However, in February 2016 the upgrade keys became available free of charge.

Satellite software uses a set of parameters known as Keplers (or, more formally, 'Keplerian elements') to accurately predict the times and durations of satellite passes. These also enable accurate positioning of map overlays on the received images. The Keplers must be updated from time to time from the Internet, typically

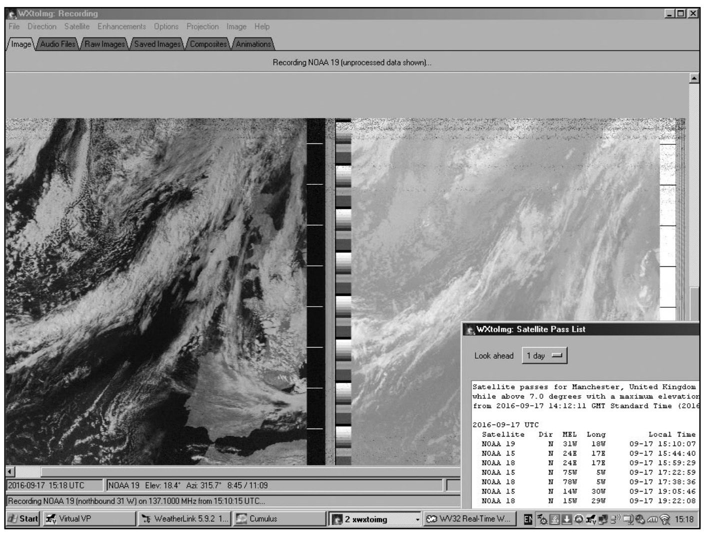

Figure 5 - Screen capture of WXtoImg recording NOAA 19 APT

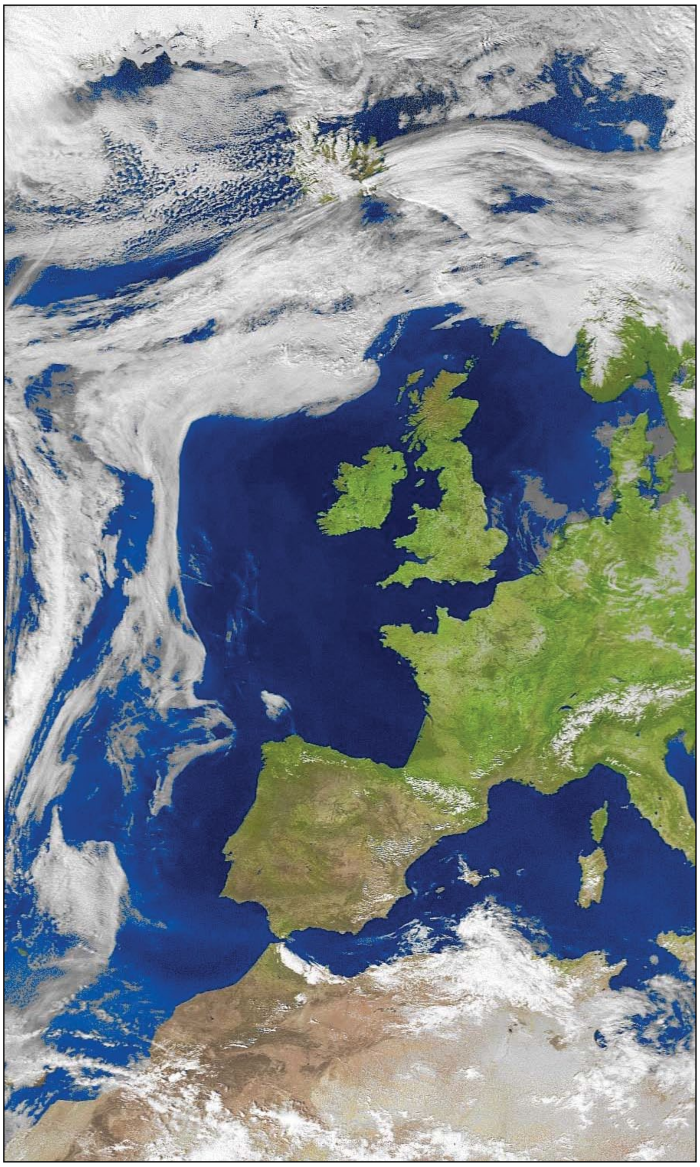

Figure 6 - HVCT enhancement of an APT signal

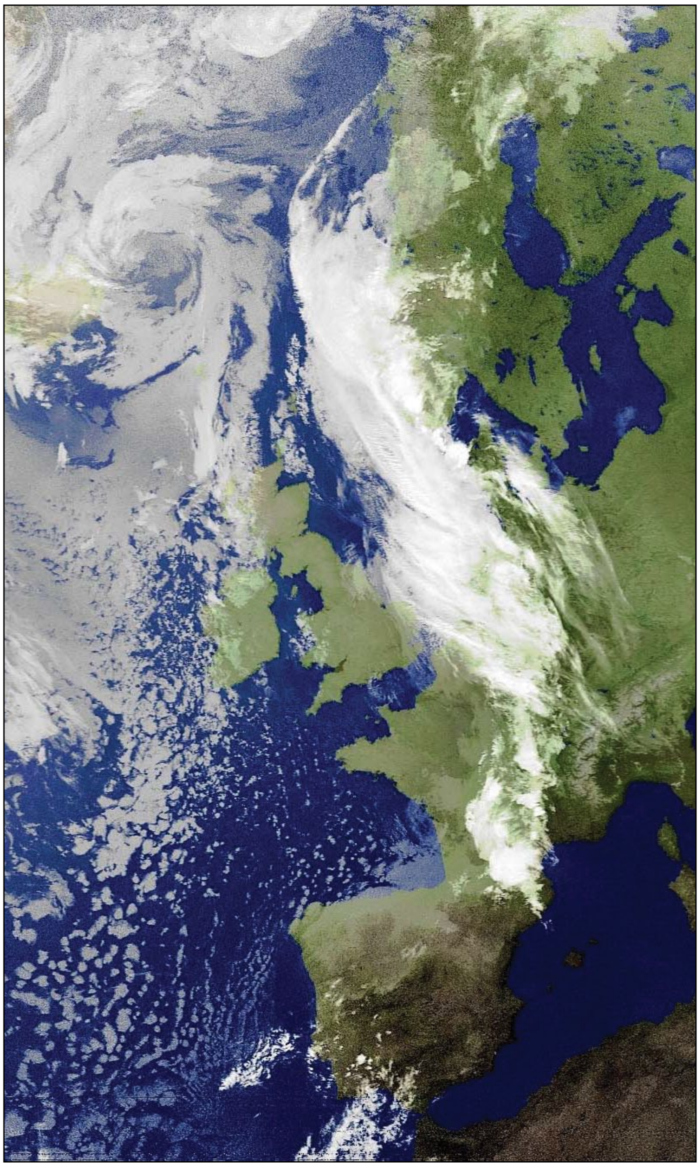

Figure 7: An MCIR enhancement of an APT Signal.

every two days or so. Updating the Keplers is does not require any understanding of the numerical parameters on the part of the user and is achieved by a single click in the file menu of WXtoImg. The software may be set to automatically record and process data from satellite passes, and so may be left unattended. The software will also drive a USB or serial interface to set a suitably equipped receiver to the correct frequency for each satellite during its pass. The R2ZX receiver used by the author has a serial interface. Its successor, the R2FU, and the WRAASE electronic APT-06 have USB interfaces. The software may be set to record only when a specified minimum elevation above the horizon is reached, and to ignore satellite passes which fail to reach a specified threshold at maximum elevation. Careful adjustment of these parameter avoids recording and attempting to process noisy signals that will produce only grainy images.

Further Information

The analogue APT format discussed in this article is being phased out, and if future polar orbiting satellites provide any transmission suitable for reception by the amateur enthusiast on 137 MHz it will probably be in the low rate picture transmission (LRPT) digital format. There are already two Russian LEO satellites in operation that provide LRPT, Meteor M N1 and Meteor M N2. Unfortunately, Meteor M N1 is now incapable of imaging the Earth due to an attitude loss on March 20, 2016 which left its sensors pointing towards the sun. However, Meteor M N2 remains operational transmitting LRPT on a frequency of 137.9 MHz. The bandwidth used by LRPT is 150 kHz, much wider than that used for APT. Because of this, reception of LRPT requires new hardware (for example, the Newsky SDR dongle mentioned above) and software. Details appear in the web links section.

There are many useful web resources for the NOAA POES satellites, and some of these are given in the web links section below. GEO continue to provide support and up-to-date information for weather satellite enthusiasts, and the GEO Shop stocks specialised items of hardware for APT, LRPT and EUMETCast reception, with discounts for members. Finally, the Radio Society of Great Britain (RSGB) is the UK's internationally recognised national society for all radio amateurs, and provides information and guidance on all aspects of radiocommunication. Individual membership of the RSGB currently costs £51 per year, and includes twelve issues of the members' magazine *RadCom*.

Despite there being a wealth of near real-time satellite images available on the web, there is still excitement and a sense of achievement in receiving images direct from the satellites. It is hoped that this article will inspire readers who have not already done so to try experimentation with reception of APT for themselves.

Web links:

- WXtoImg ("Weather to Image") software
  http://www.wxtoimg.com/
- National Oceanic and Atmospheric Administration (NOAA)
  http://www.noaa.gov/
- NOAA POES Operational Status
  http://www.ospo.noaa.gov/Operations/POES/status.html
- Polar orbiting satellite and geostationary satellite weekly status
  http://phqfh.co.uk/status.htm
- EUMETSAT near real-time images
  http://www.eumetsat.int/website/home/Images/RealTimeImages/index.html
- WRAASE electronic (hardware)
  http://www.wraase.de/shop.html
- LRPT Tutorial
  http://www.rtl-sdr.com/rtl-sdr-tutorial-receiving-meteor-m-n2-lrpt-weather-satellite-images-rtl-sdr/
- Radio Society of Great Britain
  http://rsgb.org

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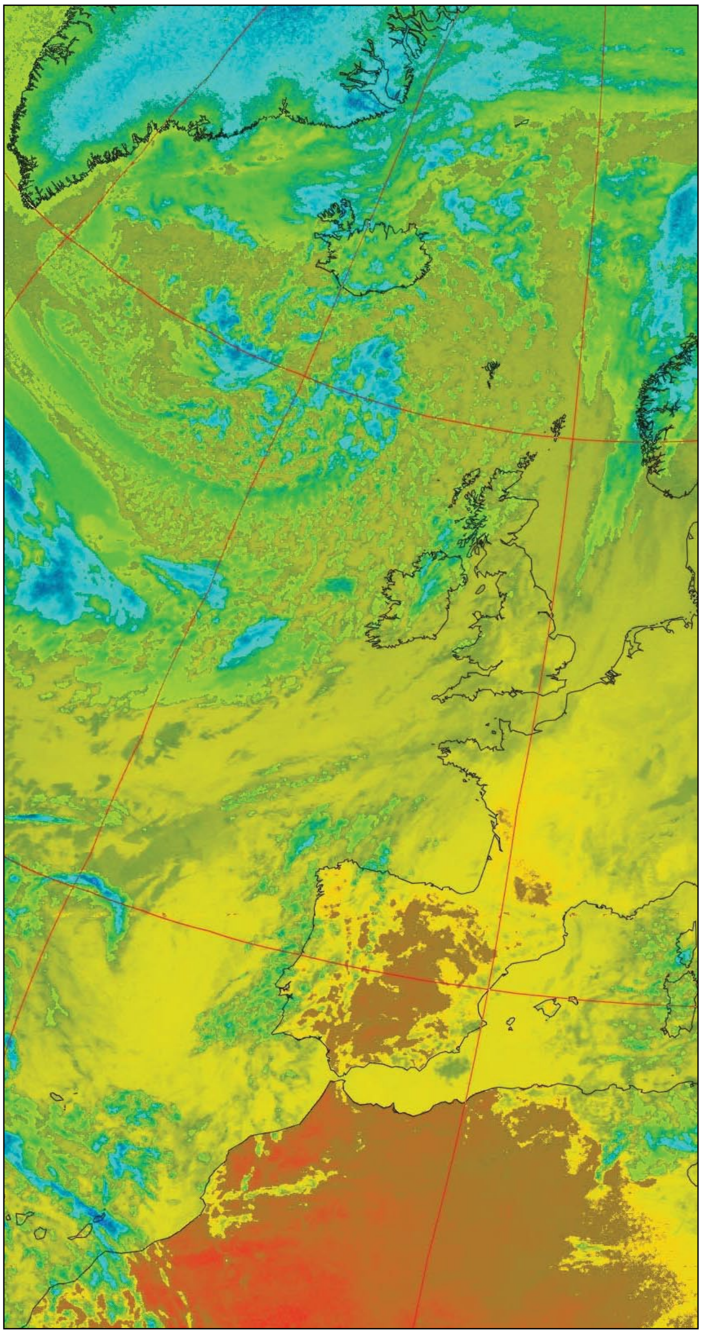
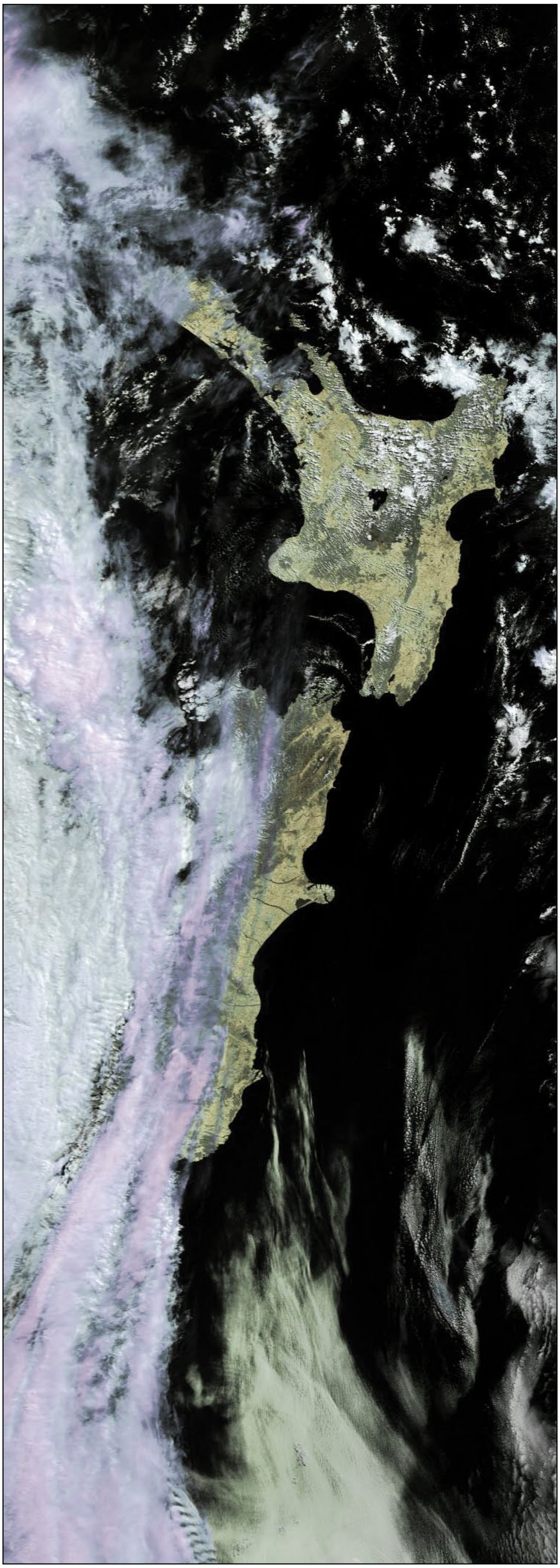


Figure 8: Thermal enhancement of APT signal.



This is a Metop-B image of New Zealand acquired on October 31, 2016 by Mike Stevens.
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Sea Ice

Michon Scott and Kathryn Hansen

A special feature from the NASA Earth Observatory Newsroom

Sea ice is frozen seawater that floats on the ocean surface. It forms in both the Arctic and the Antarctic in each hemisphere's winter; it retreats in the summer, but does not completely disappear. This floating ice has a profound influence on the polar environment, influencing ocean circulation, weather, and regional climate.

Figure 1 - Sea ice plays an important role in the climate and ecosystems of the Arctic and Antarctic.
Photograph ©2008 fruchtzwerg's world

As ice crystals form at the ocean surface they expel salt, which increases the salinity of the underlying waters. This cold, salty water is denser, and can sink to the ocean floor, where it flows back toward the equator. The sea ice layer also restricts wind and wave action near coastlines, lessening coastal erosion and protecting ice shelves. Sea ice also creates an insulating cap across the ocean surface, which reduces evaporation and heat loss to the atmosphere. As a result, the weather over ice-covered areas tends to be colder and drier than it would be without ice.

Sea ice also plays a fundamental role in polar ecosystems. When the ice melts in the summer it releases nutrients into the water, stimulating the growth of phytoplankton, the centre of the marine food web. As the ice melts, it exposes ocean water to sunlight, spurring photosynthesis in phytoplankton. When ice freezes, the underlying water becomes saltier, and sinks, mixing the water column and bringing nutrients to the surface. The ice itself is habitat for animals such as seals, Arctic foxes, polar bears, and penguins. Life thrives along the margins of sea ice, as melting and freezing enhance circulation and bring nutrients to the surface. Those nutrients nourish phytoplankton and ultimately animals like killer whales that are farther up the food chain.

The influence of sea ice on the Earth is not just regional: it's global. The white surface reflects far more sunlight back to space than ocean water does: in scientific terms, ice has a high albedo. Once sea ice begins to melt, a self-reinforcing cycle often begins: as more ice melts and exposes more dark water, ever more sunlight is absorbed. The sun-warmed water then melts more ice. Over several years, this positive feedback cycle (the ice-albedo feedback) can influence global climate.

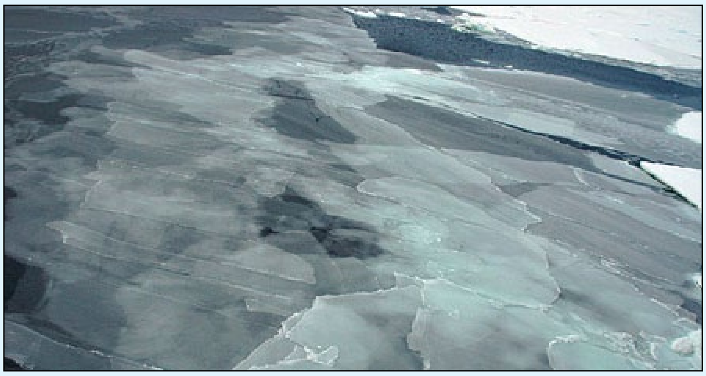

Figure 2 - Nilas Ice
Photo: Don Perovich, Cold Regions Research and Engineering Laboratory

Figure 3 - Pancake ice
Photo: Don Perovich, Cold Regions Research and Engineering Laboratory

Figure 4 - Ice Rafts
Photo: Don Perovich, Cold Regions Research and Engineering Laboratory

Figure 5 - Ice Pressure Ridges
Photo: *Ted Scambos, National Snow and Ice Data Center*

Contrary to some public misconceptions, sea ice does not influence sea level. Because it is already floating in the ocean, sea ice is already displacing its own weight of water. Melting sea ice won't raise ocean levels any more than melting ice cubes will cause a glass of ice water to overflow.

The Sea Ice Life Cycle

When seawater begins to freeze, it forms tiny crystals just millimetres wide called frazil. How the crystals coalesce into larger masses of ice depends on whether the seas are calm or rough. In calm seas, the crystals form thin sheets of ice, nilas, so smooth that they have an oily or greasy appearance. These wafer-thin sheets of ice slide over each other and form rafts of thicker ice. In rough seas, ice crystals converge into slushy pancakes. These pancakes slide over each other to form smooth rafts, or they collide into each other, creating ridges on the surface and keels on the bottom.

Sea ice begins as thin sheets of smooth nilas in calm water (figure 2) or disks of pancake ice in choppy water (figure 3). Individual pieces pile up to form rafts and eventually solidify (figure 4). Over time, large sheets of ice collide, forming thick pressure ridges along the margins (figure 5).

Some sea ice holds fast to a coastline or the sea floor—'fast ice'—while pack ice drifts with winds and currents. Because pack ice is dynamic, pieces can collide and form much thicker ice. Leads—narrow, linear openings ranging in width from metres to kilometres—continually form and disappear.

Larger and more persistent openings, polynyas, are sustained by upwelling currents of warm water or steady winds that blow the ice away from a spot as quickly as it forms. Polynyas often occur along coastlines when winds blow persistently offshore. As water and air temperatures rise each summer near the Poles, some sea ice melts. Differences in geography and climate cause Antarctic sea ice to melt more completely in the summer than Arctic sea ice.

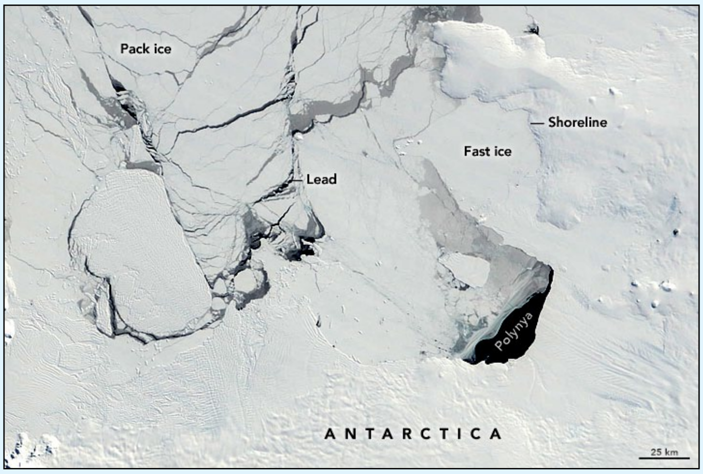

Figure 6 - This satellite image shows sea ice features: fast ice, pack ice, a polynya, and leads.
NASA satellite image courtesy Jacques Descloitres, MODIS Rapid Response Team.

Ice that survives the summer melt season may last for years. For ice to thicken, the ocean must lose heat to the atmosphere. But the ice also insulates the ocean like a blanket. Eventually, the ice becomes so thick that no more heat can escape. Once the ice reaches this thickness—3 to 4 metres—further thickening isn't possible except through collisions and ridge-building.

Multiyear ice increasingly loses salt and hardens each year that it survives the summer melt. In contrast to multiyear ice, first-year ice is thinner, saltier, and more prone to melt in the subsequent summer. As of March 2015, multiyear ice accounted for just 3% of the ice cover. The rest was all first-year ice.

Monitoring Sea Ice

Dating back to 870 CE, intermittent records assembled by the Vikings record the number of weeks per year that ice occurred along the north coast of Iceland. Other scattered records of Arctic sea ice date back to the mid 1700s, when sailors kept notes on Northern Hemisphere shipping lanes. Global air temperature records date back to the 1880s and can offer a stand-in for Arctic sea ice conditions; but such temperature records were initially collected at just eleven locations. Russia's Arctic and Antarctic Research Institute has compiled ice charts since 1933.

Early records of sea ice cover come from explorers like Robert Peary, who attempted to reach the North Pole in 1909. But expeditions were sporadic and only surveyed their immediate environment, so their records are far from comprehensive. Today, scientists studying Arctic sea ice trends can rely on a fairly comprehensive record dating back to 1953. They use a combination of satellite records, shipping records, and ice charts from several countries.

Figure 7 - A coloured photograph of members of Peary's 1909 expedition crossing an open lead on Arctic sea ice. Credit: Library of Congress Prints and Photographs Division

In the Antarctic, data prior to the satellite era are even more sparse. To extend the historical record of Southern Hemisphere sea ice back in time, scientists have been investigating two types of proxies. One reference is the records kept by Antarctic whalers since the 1930s, which document the location of all whales caught. Because whales tend to congregate and feed near the sea ice edge, their locations could be a proxy for ice extent.

A second proxy is the detection of phytoplankton-derived organic compounds in Antarctic ice cores. Since phytoplankton grow most abundantly along the edges of the ice, the concentration of sulphur-containing compounds has been proposed as an indicator of how far the ice edge extended from the continent. Currently, only the satellite record is considered sufficiently reliable for studying Antarctic sea ice trends.

Since 1979, a collection of satellites has provided a continuous, nearly complete record of Earth's sea ice cover. Valuable data are collected by satellite sensors that observe the microwaves emitted by the ice surface. Unlike visible light, the microwave energy radiated by ice passes through clouds. This means it can be measured year-round, even through the long polar night.

The continuous sea ice record began with the Scanning Multichannel Microwave Radiometer (SMMR) on the Nimbus-7 satellite (1978-1987) and continued with the *Special Sensor Microwave/Imager* (SSM/I) and the *Special Sensor Microwave Imager Sounder* (SSMIS) on Defense Meteorological Satellite Program (DMSP) satellites (1987 to present). The *Advanced Microwave Scanning Radiometer–for EOS* (AMSR-E) on NASA's Aqua satellite also contributed data (2002-2011), a record that was extended with the 2012 launch of the *Advanced Microwave Scanning Radiometer 2* (AMSR2) on JAXA's GCOM-W1 satellite.

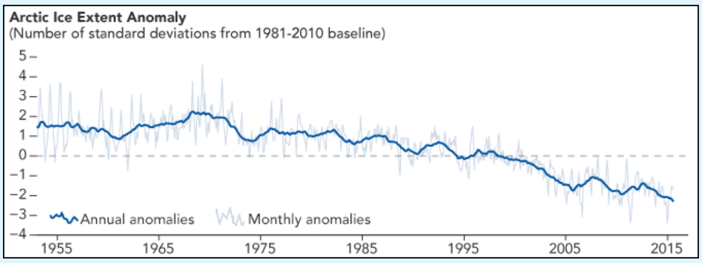

Figure 8 - This plot above shows sea ice anomalies—by how much Arctic sea ice cover was above or below the norm.
NASA Earth Observatory graph by Joshua Stevens, using NSIDC data provided by Walt Meier/NASA Goddard.

Reliable records of Arctic sea ice began in 1953, and satellites have offered a near-continuous record since 1979. The plot above shows sea ice anomalies—how much Arctic sea ice cover was above or below the norm.

Because ocean water emits microwaves differently from sea ice, such ice 'looks' different to a satellite sensor. These observations are processed into digital picture elements, or pixels, each representing a 25 × 25 kilometre square. Scientists estimate the amount of sea ice in each pixel.

There are two ways to express Earth's total polar ice cover: ice area and ice extent. To estimate area, scientists calculate the percentage of sea ice in each pixel, multiply by the pixel area, and add up the amounts. To estimate ice extent, scientists set a threshold percentage, and count every pixel that meets or exceeds that threshold as 'ice-covered.' The National Snow and Ice Data Center, one of NASA's Distributed Active Archive Centers, monitors sea ice extent using a threshold of 15%.

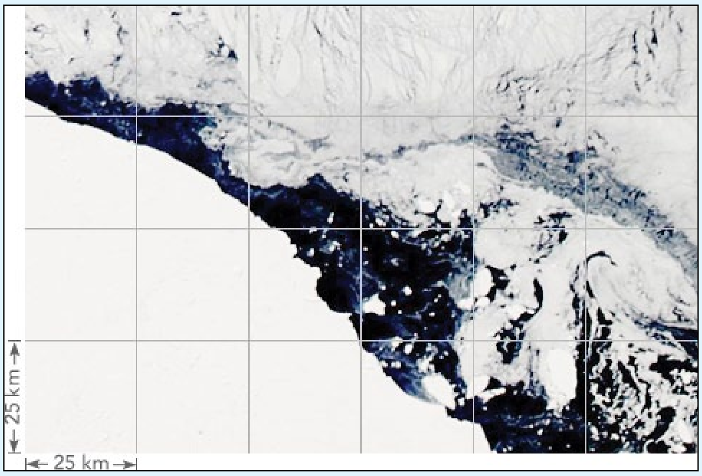

Figure 9 - Satellites measure sea ice concentration on a 25 kilometre by 25 kilometre grid. This image illustrates the area covered by each pixel of the low-resolution microwave instruments superimposed on a higher-resolution, colour satellite image. Sea ice concentration is the percentage of each pixel that is covered by ice. Sea ice extent is calculated by adding up the pixels with an ice concentration of at least 15%.
NASA Earth Observatory image by Joshua Stevens and Robert Simmon, based on MODIS data.

The threshold–based approach may seem less accurate, but it has the advantage of being more consistent. When scientists are analysing satellite data, it is easier to say whether there is or isn't at least 15% ice cover in a pixel, than it is to say, for example, whether the ice cover is 70% or 75%. By reducing the uncertainty in the amount of ice, scientists can be more certain that changes over time are real.

Beyond measuring ice coverage, satellites can also help scientists get a better handle on ice thickness. In 2010, the European Space Agency launched the CryoSat-2 satellite, which carries the *Synthetic Aperture Interferometric Radar Altimeter* (SIRAL). Data from this instrument are converted into maps of sea ice thickness—a useful tool for tracking change over time and for monitoring winter season ice growth.

Researchers also monitor sea ice using aircraft. In the summer of 2016, for example, NASA's Operation IceBridge mapped the extent, frequency, and depth of melt ponds that form on top of the sea ice during the melt season. The number of melt ponds that form early in the season can affect the minimum extent reached by sea ice in September. Operation IceBridge has monitored sea ice during late winter since 2009.

Arctic Sea Ice

Arctic sea ice occupies an ocean basin largely enclosed by land. Because there is no landmass at the North Pole, sea ice extends all the way to the pole, making the ice subject to the most extreme oscillations between wintertime darkness and summertime sunlight. Likewise, because the ocean basin is surrounded by land, ice has less freedom of movement to drift into lower latitudes and melt. Sea ice also forms in areas south of the Arctic Ocean in winter, including the Sea of Okhotsk, the Bering Sea, Baffin Bay, Hudson Bay, the Greenland Sea, and the Labrador Sea.

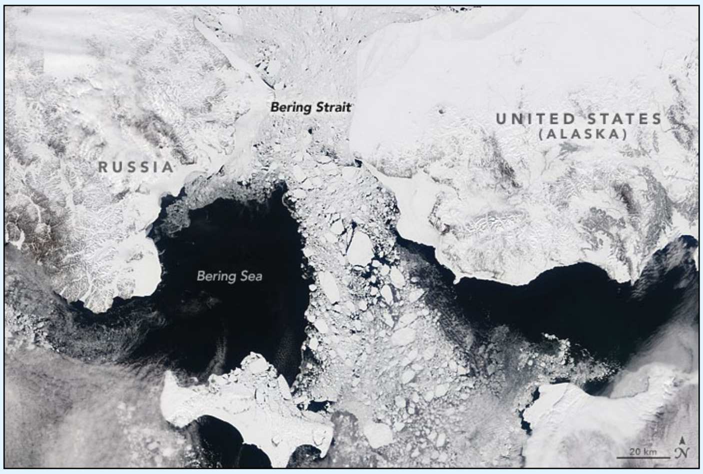

Figure 10 - The Bering Strait is one of the few outlets through which sea ice exits the Arctic Ocean.
NASA Earth Observatory image by Joshua Stevens and George Riggs using data from Terra MODIS.

Arctic sea ice generally reaches its maximum extent each March and its minimum extent each September. This ice has historically ranged from roughly 14-16 million square kilometres (Mkm^2) in late winter to roughly 7 Mkm^2 each September. In recent years, however, those numbers have been much lower.

On time scales of years to decades, the dominant cause of atmospheric variability around the North Pole is the *Arctic Oscillation* (AO), an atmospheric seesaw, in which air masses shift between the polar regions and mid-latitudes.

The shifting can intensify, weaken, or move the location of semi-permanent low and high-pressure systems. These changes influence the strength of the prevailing westerly winds and the track that storms tend to follow.

During the ‘positive’ phase of the AO, winds intensify, which increases the size of leads in the ice pack. The thin, young ice that forms in these leads is more likely to melt in the summer. The strong winds also tend to flush ice out of the Arctic through the Fram Strait. During ‘negative’ phases of the oscillation, winds are weaker. Multiyear ice is then less likely to be swept out of the Arctic basin into the warmer waters of the Atlantic.

However, in recent years, the relationship between the Arctic Oscillation and summer sea ice extents has weakened. For example, a strong negative phase in the winters of 2009 and 2010 was not enough to maintain high levels of ice cover. Clearly some other factors can override the relationship.

Status and Trends

In September 2015, Arctic sea ice reached a minimum extent of 4.41 Mkm^2—the fourth lowest in the satellite record. The ice then grew during the winter months and reached its annual maximum extent in March 2016, measuring 14.52 Mkm^2. By September 2016, sea ice dropped to 4.14 Mkm^2, the second lowest extent of the satellite era (figure 11).

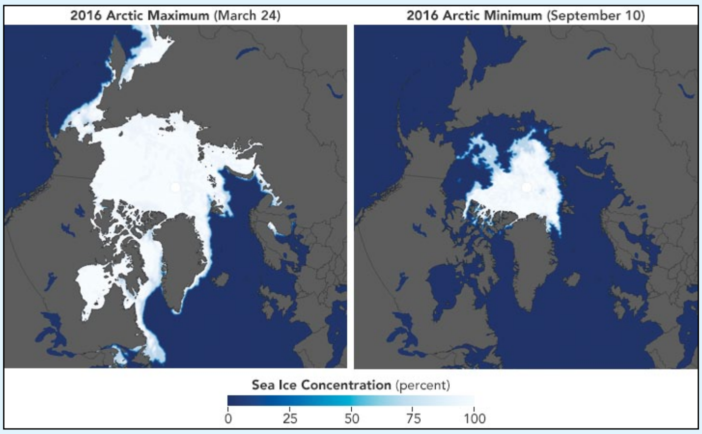

Figure 11 - The minimum Arctic sea ice extent occurs in September. The maximum is in February or March. Arctic sea ice maxima and minima have been shrinking for three decades.
NASA Earth Observatory maps by Joshua Stevens, based on AMSR2-E data from NSIDC.

The record lowest minimum occurred in September 2012 when sea ice plummeted to 3.41 Mkm^2. That was well below the previous record of 4.17 Mkm^2 set in 2007, when Arctic sea ice extent broke all prior records by mid-August, more than a month before the end of melt season. Since the mid 2000s, low minimum extents in the Arctic have become the ‘new normal.’

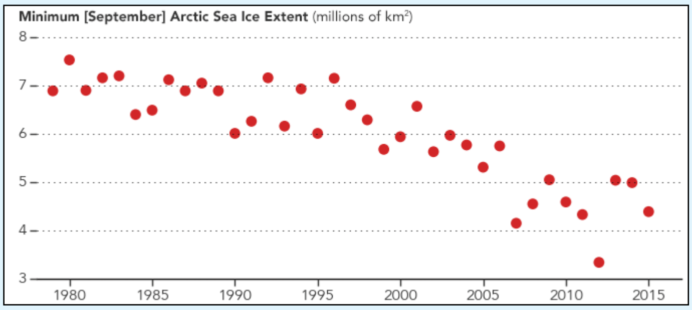

Figure 12 - Since 1979, the monthly September ice extent has declined 13.4% per decade relative to the average from 1981 to 2010.
NASA Earth Observatory graph by Joshua Stevens, based on data from the National Snow and Ice Data Center.

Between 1979 and 2015, the average monthly extent for September declined by 13.4% per decade. In every geographic area, in every month, and every season, Arctic sea ice extent is lower today than it was during the 1980s and 1990s.

Natural variability and Global Warming both appear to have played a role in this decline. The AO’s strongly positive mode through the mid 1990s flushed thicker, older ice out of the Arctic, replacing multiyear ice with first-year ice that is more prone to melting. After the mid 1990s, the AO was often neutral or negative, but sea ice failed to recover. Instead, a pattern of steep Arctic sea ice decline began in 2002. The AO probably triggered a phase of accelerated melt that continued into the next decade because of unusually warm Arctic air temperatures.

Year	Average Minimum (Mkm^2)	Extent Relative to 1981-2010 Average (Mkm^2)	Difference from 1981-2010 Average (%)
2002	5.95	-0.55	-8.53
2003	6.13	-0.37	-5.76
2004	6.04	-0.46	-7.15
2005	5.56	-0.94	-14.53
2006	5.91	-0.59	-9.15
2007	4.29	-2.22	-34.05
2008	4.72	-1.79	-27.44
2009	5.38	-1.13	-17.29
2010	4.92	-1.59	-24.37
2011	4.61	-1.90	-29.13
2012	3.62	-2.89	-44.35
2013	5.35	-1.16	-17.76
2014	5.28	-1.23	-18.83
2015	4.63	-1.88	-28.82

Arctic ice extent has dropped steeply since 2002.
Table based on data from the National Snow and Ice Data Center.

Many global climate models predict that the Arctic will be ice-free for at least part of the year before the end of the 21st century. Some models predict an ice-free Arctic by mid-century. Depending on how much Arctic sea ice continues to melt, the ice could become extremely vulnerable to natural variability in cycles such as the Arctic Oscillation.

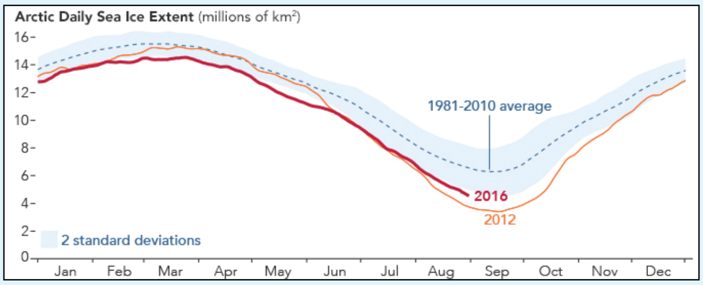

Figure 13 - Arctic sea ice cover peaks each year in March, and reaches its minimum in September. In 2012, Arctic ice reached the lowest extent ever recorded, well below the historical average (blue dashed line).
Earth Observatory graph by Joshua Stevens, based on data from the National Snow and Ice Data Center.

Declining sea ice will lead to a loss of habitat for seals and polar bears; it also should increase encounters between polar bears and humans. Indigenous peoples in the Arctic have already described changes in the health and numbers of polar bears.

As sea ice retreats from coastlines, wind-driven waves—combined with thawing permafrost—will very likely lead to more rapid coastal erosion. Other potential impacts include changed weather patterns. This is an area of active research, as scientists try to tease out the possible links between sea ice loss and mid-latitude weather patterns.

Figure 14 - The loss of sea ice exposes shorelines to the full force of wind and waves, resulting in rapid erosion. This cabin fell into the Beaufort Sea, a region where some coastlines retreated more than 24 metres in 2007.
Photograph courtesy Benjamin Jones, USGS.

Some researchers have hypothesised that melting sea ice could interfere with ocean circulation. In the Arctic, ocean circulation is driven by the sinking of dense, salty water. Fresh meltwater, coming primarily from the Greenland Ice Sheet, could interfere with ocean circulation at high latitudes, slowing it down. Changes in the location and timing of sea ice growth—where the dense salty waters are formed and then sink to the bottom—may also be an important factor.

Antarctic Sea Ice

The Antarctic is in some ways the opposite of the Arctic. The Arctic is an ocean basin surrounded by land, with the sea ice corralled in the coldest, darkest part of the Northern Hemisphere. The Antarctic is a continent surrounded by ocean. Whereas Northern Hemisphere sea ice can extend from the North Pole to a latitude of 45°N (along the northeast coasts of Asia and North America), most of the ice is found above 70°N. Southern Hemisphere sea ice does not get that close to the South Pole; it fringes the continent and reaches to 55°S latitude at its greatest extent.

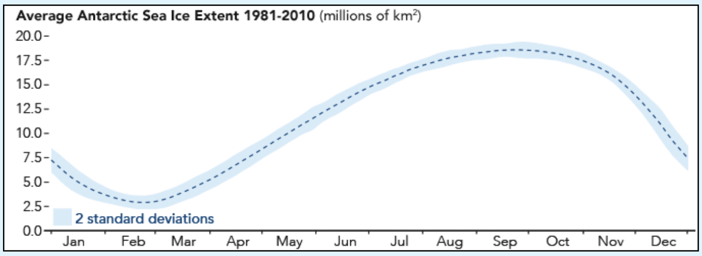

Figure 15 - Sea ice around Antarctica peaks in September and reaches a minimum in February. Roughly 15 million square kilometres of ice melt and freeze during the annual cycle.
NASA Earth Observatory graph by Joshua Stevens, based on data from the National Snow and Ice Data Center.

Because of this geography, Antarctic sea ice coverage is larger than the Arctic's in winter, but smaller in the summer. Total Antarctic sea ice peaks in September—the end of Southern Hemisphere winter—historically rising to an extent of roughly 17-20 Mkm^2 . Ice extent reaches its minimum in February, when it dips to roughly 3-4 Mkm^2.

To study patterns and trends in Antarctic sea ice, scientists commonly divide the ice pack into five sectors: the Weddell Sea, the Indian Ocean, the western Pacific Ocean, the Ross Sea, and the Bellingshausen and Amundsen seas (figure 16). In some sectors, it is common for nearly all the sea ice to melt in the summer.

Antarctic sea ice is distributed around the entire fringe of the continent—a much broader area than the Arctic—and it is exposed to a broader range of land, ocean, and atmospheric influences. Because of the geographic and climatic diversity, Antarctic sea ice is more variable from year to year and climate oscillations don't affect ice in all sectors the same way. For these reasons, it is more difficult to generalise the influence of climate patterns to the entire Southern Hemisphere ice pack.

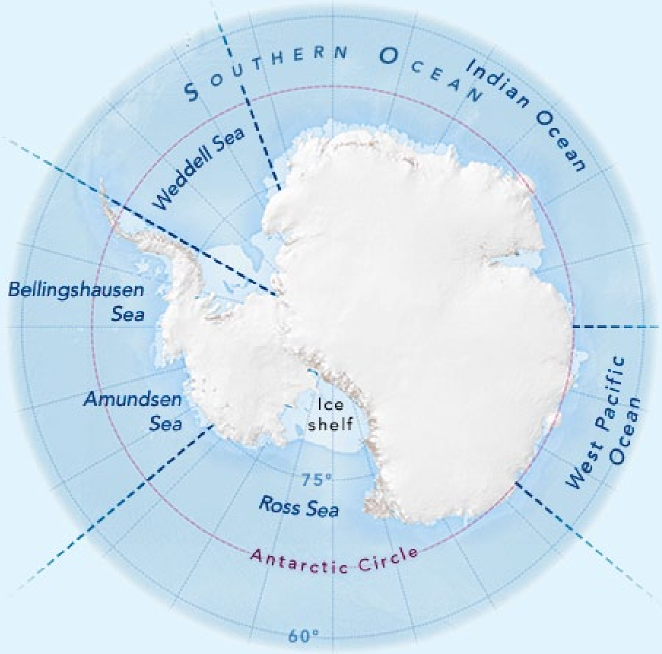

Figure 16 - In the Southern Ocean, sea ice fringes the entire Antarctic continent. Researchers typically subdivide Antarctic sea ice into five sectors, each influenced by different geography and weather conditions.
NASA Earth Observatory map by Joshua Stevens, based on data from the Norwegian Polar Institute and Natural Earth.

Antarctica experiences atmospheric oscillations and recurring weather patterns that influence sea ice extent. The primary variation is the Antarctic Oscillation, also called the *Southern Annular Mode*. Like the Arctic Oscillation, the Antarctic Oscillation involves a large-scale see-sawing of atmospheric mass between the pole and the mid-latitudes. This oscillation can intensify, weaken, or shift the location of low- and high-pressure weather systems. These changes influence wind speeds, temperature, and the track that storms follow, any of which may influence sea ice extent.

During positive phases of the Antarctic Oscillation, the prevailing westerly winds that circle Antarctica strengthen and move southward. This can change the way ice is distributed among the various sectors. The strengthening of the westerlies also isolates much of the continent and tends to have an overall cooling effect. However, it does cause dramatic warming on the Antarctic Peninsula, as warmer air above the oceans to the north is drawn southward. Winds may drive the ice away from the coast in some areas and toward the coast in others. Thus, the same climate influence may lessen sea ice in some sectors and increase it in others.

Changes in the El Niño-Southern Oscillation Index (ENSO), an oscillation of ocean temperatures and surface air pressure in the tropical Pacific, can lead to a delayed response (three to four seasons later) in Antarctic sea ice extent. In general, El Niño leads to more ice in the Weddell Sea and less ice on the other side of the Antarctic Peninsula, while La Niña causes the opposite conditions.

Another bit of atmospheric variability is the periodic strengthening and weakening of something meteorologists call ‘zonal wave three’, or ZW3. This pattern alternately strengthens winds that blow cold air away from Antarctica (toward the equator) and winds that bring warmer air from middle latitudes toward Antarctica. When southerly winds intensify, more cold air is pushed to lower latitudes, and sea ice tends to increase. The effect is most apparent in the Ross and Weddell Seas and near the Amery Ice Shelf.

As in the Arctic, the interaction of natural cycles is complex, and researchers continue to study how these forces interact and control the Antarctic sea ice extent.

Status and Trends

In October 2015, Antarctic sea ice peaked for the year at 18.8 Mkm^2. That’s smaller than the previous three years, but falls just about in the middle of maximum extents measured since 1979. By February 2016, just a small fraction of that ice remained, reaching an annual minimum extent of 2.6 Mkm^2—the ninth lowest in the satellite record (figure 17).

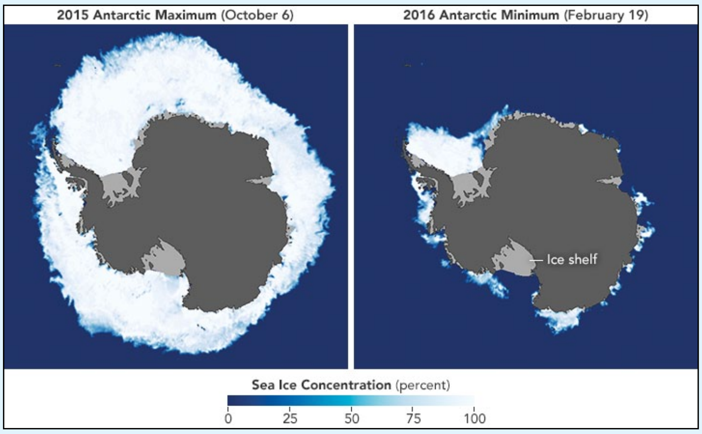

Figure 17 - Antarctic sea ice peaks in September or October, and reaches a minimum in February. In some places, sea ice melts completely in the summer.
NASA Earth Observatory maps by Joshua Stevens, using AMSR2 data supplied by GCOM-W1/JAXA.

Since 1979, the total annual Antarctic sea ice extent has increased about 1% per decade. Compared with the Arctic, the signal has been a ‘noisy’ one, with wide year–to-year fluctuations. For three consecutive Septembers (2012 to 2014), satellites observed new record highs for winter sea ice extent around Antarctica. The largest of those occurred in September 2014, when the ice reached 20.14 Mkm^2. Still, increases in Antarctic sea ice are exceeded by decreases in the Arctic; that is to say, global sea ice is decreasing even as Antarctic sea ice is increasing slightly.

Unlike the Arctic, where the downward trend is consistent in all sectors, in all months, and in all seasons, the Antarctic picture is more complex. Although sea ice cover expanded in most of the Southern Ocean between 1979 and 2013, it decreased substantially in the Bellingshausen and Amundsen seas. These two seas are close to the Antarctic Peninsula, a region that has warmed significantly in recent decades.

The variability in Antarctic sea ice patterns in different sectors and from year to year makes it difficult to predict how Antarctic ice could change as greenhouse gases continue to warm the Earth. Climate models predict that Antarctic sea ice will respond more slowly than Arctic sea ice, but as temperatures continue to rise, a long-term decline is expected.

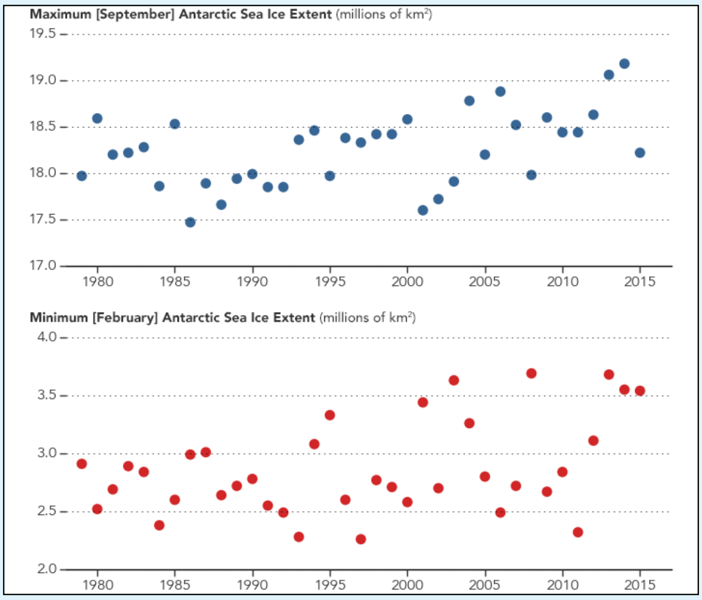

Figure 18 - Antarctic sea ice does not plainly show the effects of global warming. There is little evidence of long-term change in either the maximum (September) or minimum (February) ice extent.
NASA Earth Observatory graph by Joshua Stevens, based on data from the National Snow and Ice Data Center.

Why do the negative trends in Arctic sea ice seem to be more important to climate scientists than the increase in Antarctic ice? Part of the reason is that the size of the increase is much smaller and slightly less certain than the Arctic trend.

Another reason is that the complete summertime disappearance of Northern Hemisphere ice would be a dramatic departure from what has occurred throughout the satellite record and likely throughout recorded history. In the Antarctic, however, sea ice already melts almost completely each summer. Even if it completely disappeared in the summer, the impact on the Earth’s climate system would probably be much smaller than a similar disappearance of Arctic ice.

You might wonder how Antarctic sea ice could be increasing while global warming is raising the planet’s average surface temperature. It’s a question scientists are asking, too. One reason may be that other atmospheric changes are softening the influence of global warming on Antarctica. For example, the ozone hole that develops over Antarctica each spring actually intensifies a vortex of winds that circles the South Pole. The stronger this vortex becomes, the more isolated the Antarctic atmosphere becomes from the rest of the planet. In addition, ocean circulation around Antarctica behaves differently than it does in the Arctic. In the Southern Ocean, warm water tends to sink downward in the ocean’s water column, making sea ice melt from warm water less likely.

One concern related to Antarctic sea ice loss is how the relationship between land and sea ice will change. Ice shelves partly rest on land and partly float, and sea ice is thought to stabilise the edges of these shelves. Ice shelves frequently calve icebergs—a natural process that

Figure 19 - Icebergs are not sea ice: they're floating fragments of glaciers or ice shelves. Iceberg formation (and ice shelf retreat) may increase in regions of Antarctica where sea ice is declining because sea ice protects ice shelves by cooling air temperatures and dampening waves.
Photograph courtesy Patrick Rowe, NSF Antarctic Photo Library.

is not necessarily a sign of climate change. But the rapid disintegration and retreat of an ice shelf (such as the collapse of Larsen B in 2002) is a warming signal.

Although sea ice is too thin to physically buttress an ice shelf, intact sea ice may preserve the cool conditions that stabilise a shelf. Air masses passing over sea ice are cooler than air masses passing over open ocean. Sea ice may also suppress ocean waves that would otherwise flex the shelf and speed ice shelf breakup.

The interaction between sea ice loss and ice shelf retreat merits careful study because many ice shelves are fed by glaciers. When an ice shelf disintegrates, the glacier feeding it often accelerates. Because glacier acceleration introduces a new ice mass into the ocean, it can raise global sea levels. So while sea ice melt does not directly lead to sea level rise, it could contribute to other processes that do. Glacier acceleration has already been observed on the Antarctic Peninsula.

Conclusion

Because of differences in geography and climate, the amount, location, and natural variability of sea ice in the Arctic and the Antarctic are different. Global warming and natural climate patterns may affect each hemisphere's sea ice in different ways or at different rates. Within each hemisphere, sea ice can change substantially from day to day, month to month, and even over the course of a few years.

Figure 20 - The Sun hangs low on the horizon above solidified pancake ice in the Arctic Ocean.
Photograph courtesy Andy Mahoney, NSIDC.

Comparing conditions at only two points in time or examining trends over a short period is not sufficient to understand the impact of long-term climate change on sea ice. Scientists can only understand how sea ice is changing by comparing current conditions to long-term averages.

Since 1979, satellites have provided a consistent continuous record of sea ice. Through 2015, the average monthly September extent of Arctic sea ice has declined by 13.4% per decade relative to the average from 1981 to 2010. Declines are occurring in every geographic area, in every month, and every season. Natural variability and rising temperatures linked to global warming appear to have played a role in this decline. The Arctic may be ice-free in summer before the end of this century.

Antarctic sea ice trends are smaller and more complex. Relative to the average from 1981 to 2010, the Antarctic sea ice extent increased about 1% per decade, but the trends were not consistent for all areas or all seasons. The variability in Antarctic sea ice patterns makes it harder for scientists to explain Antarctic sea ice trends and to predict how Southern Hemisphere sea ice may change as greenhouse gases continue to warm the Earth. Climate models do predict that Antarctic sea ice will respond more slowly than Arctic sea ice to warming, but as temperatures continue to rise, a long-term decline is expected.

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Sea Ice design by Joshua Stevens and Robert Simmon, September 16, 2016

Views of 'Planet Earth'

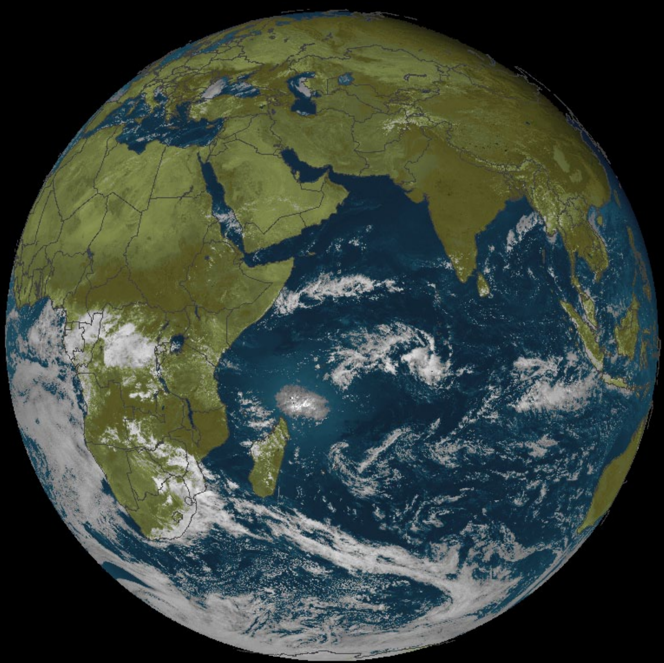
Francis Bell

While briefly sorting through some back issues of my '*Planet Earth*' magazines the cover of the Summer 2015 edition caught my eye. Previously, I had assumed that the cover showed an image taken by *Meteosat 7*, stationed over the Indian Ocean. Regular images from this satellite can be received to registered users via the *EUMETCast* service. I receive this service, so I am familiar with the visible spectrum images displayed using a colour palette in David Taylor's software.

However, I have now noticed differences between the images in question. The '*Planet Earth*' image clearly shows Antarctica and most of the west coast of Africa but not India; Meteosat 7 images show, in addition to Africa, all of India and much of Asia.

A little research has given me the answer. The '*Planet Earth*' image is a famous photograph taken on December 7, 1972 from the *Apollo 17* command module when about 29,000 km from Earth on its journey to the moon. This image has been given the title 'The Blue Marble'. Interestingly, the photograph was taken at about the same distance from the Earth as geostationary satellites, so perhaps this is some excuse for my slight confusion over the origin of the photograph. Use your own judgement by comparing the 'Planet Earth' image with a recent Meteosat 7 image.

The *Blue Marble* image on the Magazine Cover



A typical Meteosat 7 image

'Planet Earth' Autumn Edition

This is a reminder to readers who do not regularly receive '*Planet Earth*', which is available free of charge. To add your name to the publisher's mailing list, write a letter with a request to regularly receive '*Planet Earth*' to:

Planet Earth Editors,
Natural Environment Research Council (NERC),
Polaris House, North Star Avenue,
Swindon, SN2 1EU

or send an email to

requests@nerc.ac.uk

In either case, please include a full postal address and reason for you interest in their publication: e.g. personal interest, educational, scientific or other.

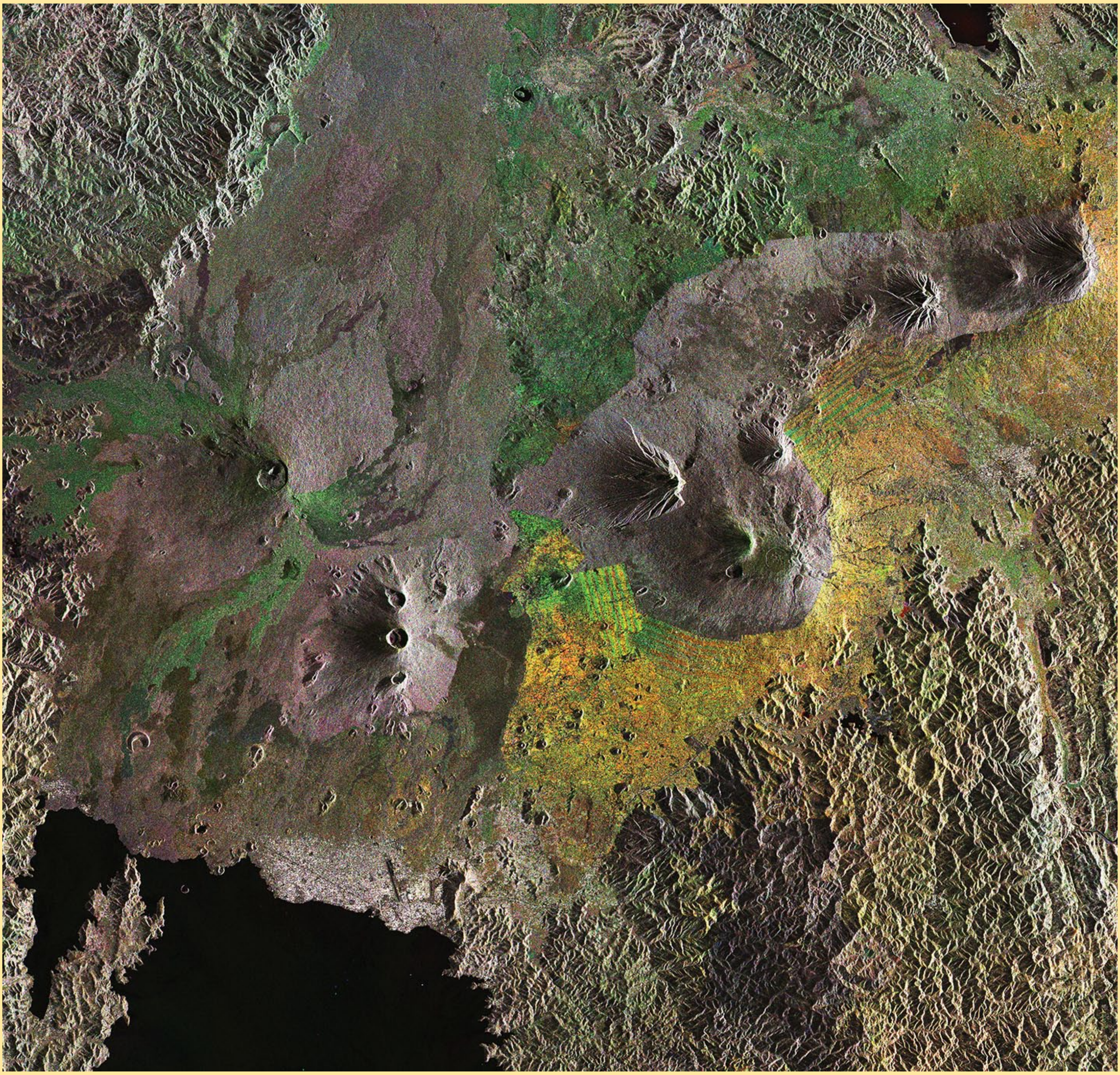
The 24-page autumn 2016 copy of 'Planet Earth' which I recently received is mainly devoted to atmospheric pollution with London as a case study. I was interested to read about airborne chemical pollutants and their toxic effects, but couldn't help feeling slightly lucky living in SW Surrey where I judge air pollution from a biological perspective.

Lichens are very sensitive to air pollution so, if you look at your local tree trunks and find them well coated with lichens, then it's likely your air quality is quite good. If you don't find that cover, the chances are that you are suffering some air pollution. This photograph below, recently taken in my garden, shows substantial lichen cover on one of my garden seats which has not been cleaned for about six years (I will clean it next spring).

Thick lichen encrusting a garden seat suggests good air quality

East Africa's Virunga Mountains

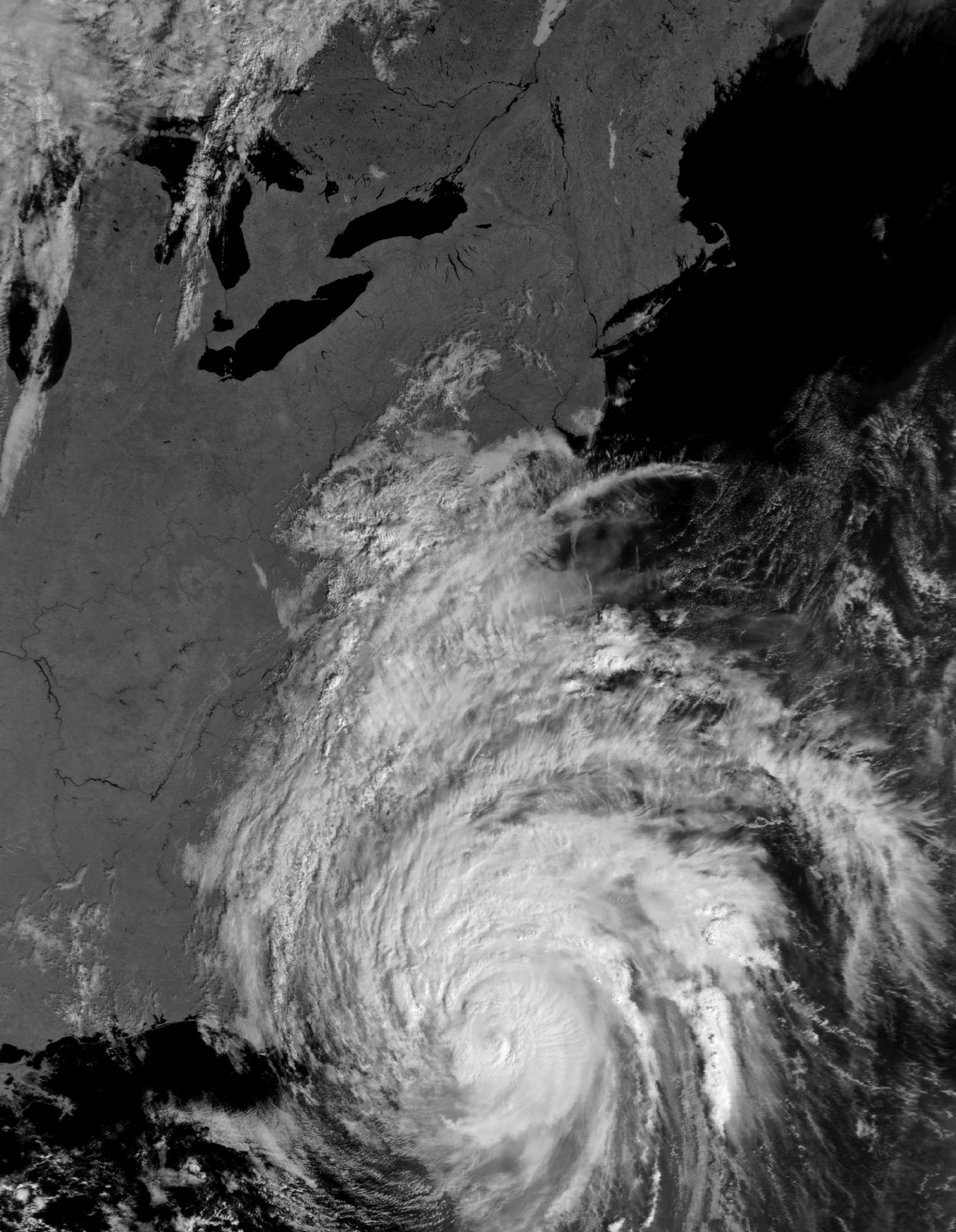
European Space Agency



This **Sentinel-1** radar composite image features the Virunga Mountains in East Africa: a chain of volcanoes stretching across Rwanda's northern border with Uganda and east into the Democratic Republic of the Congo. While most are dormant, two of the eight volcanoes are active, with the most recent eruptions in 2006 and 2010.

The mountains lie on the Albertine Rift, where the Somali Plate is splitting away from the rest of the African continent. The area is one of Africa's most biologically diverse regions, but high human population density, poverty and conflict pose a challenge to conservation. Across the mountain range, however, a series of national parks has been established to protect the fauna and flora.

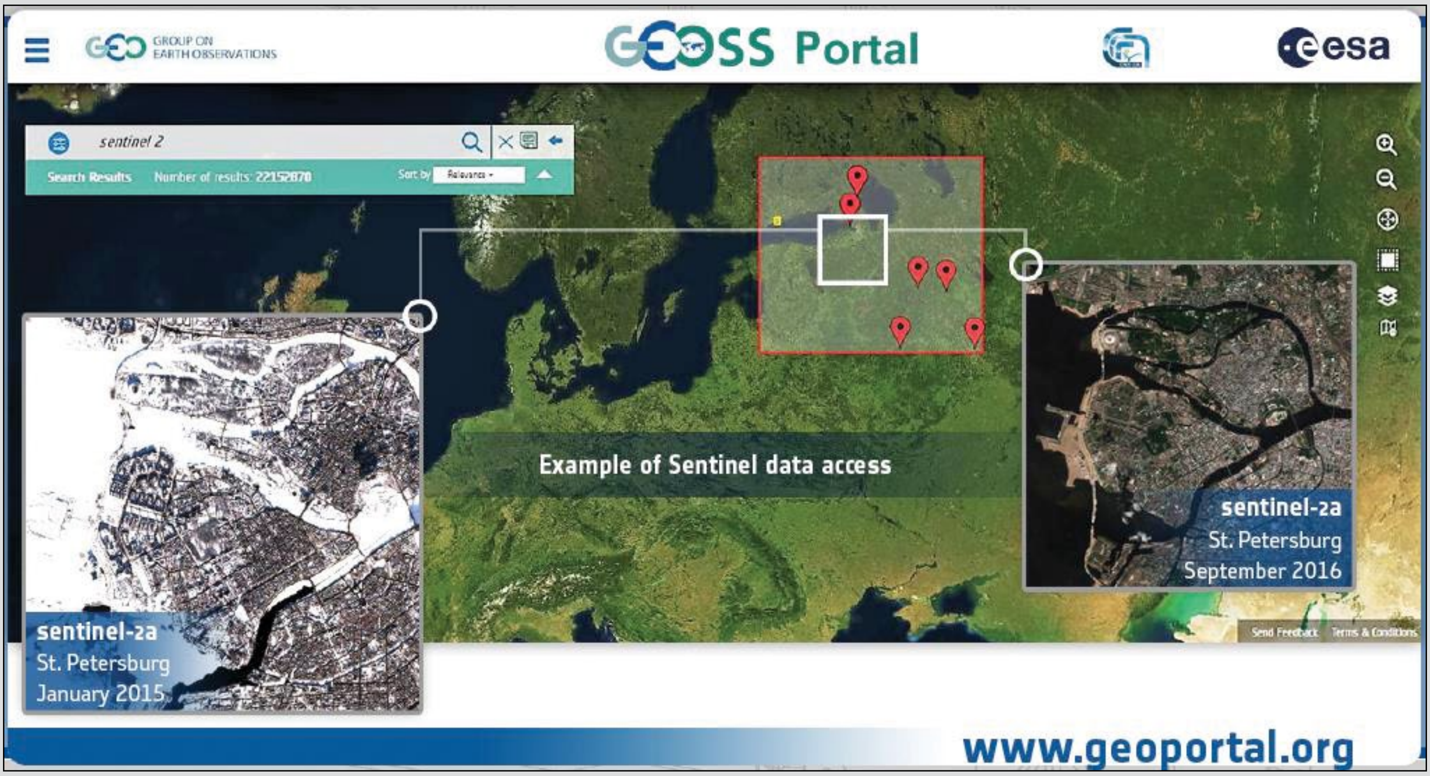
In this image, we can easily identify the delineation between the protected and non-protected lands—the green, orange and yellow dots indicate changes in the surface of non-protected lands between the radar scans that make up this composite image. These changes are primarily in vegetation as the land surrounding the mountains is blanketed with agricultural plots. In particular, we can see the grid-like pattern of agriculture, visible in the green and yellow square at the centre of the image.



This Meteor M2 channel-2 image showing Hurricane Matthew poised over Florida on October 7, 2016, was posted on the GEO-Subscribers YAHOO Group by Jeff Kelly.

Improved GEOSS Web Portal

European Space Agency



Introduction by Francis Bell

GEOSS have just opened a new portal for public use, which could be of interest to our members. Below is some text I extracted from their promotional page on the Internet at

http://www.esa.int/Our_Activities/Observing_the_Earth/Refurbished_GEOSS_portal_now_online

I view this development as a challenge to GEO Members to search the new system for a specific target, subject or image. I am a beginner in this field but I hope that others who become more experienced will feel able to offer advice on how to research this portal, and perhaps contribute articles for the benefit of readers.

Refurbished GOESS Portal now Online

A new and improved version of the **Global Earth Observation System of Systems** (GEOSS) web portal is ready to provide users with faster, more intuitive access to the ever-growing wealth of diverse Earth observation resources worldwide. The portal is the primary access point to GEOSS, connecting Earth observation data users to over 200 million resources such as satellite-based data, aerial and in-situ data, models, algorithms and web-pages.

The enhanced GEOSS portal was unveiled during the 13th annual **Group on Earth Observations** (GEO) plenary meeting held in Saint Petersburg, Russia between November 7-10, 2016.

One of the main challenges of GEOSS is that it must connect a vast amount of data amongst a large variety of users that includes decision and policy-makers, scientists and data analysts, as well as value-adders and citizens.

The new portal permits users to use simple and multicriteria searches to refine results according to their needs, as well as filter results for the type of data they want to consult: such as from a particular satellite mission. For example, users searching for cloud-free *Sentinel-2* imagery over a particular area can find what they need within a few clicks.

> 'It's never been easier to access the satellite and in situ data and information in GEOSS,' said Barbara Ryan, the Director of the GEO Secretariat. 'As we work with existing and new providers, we can be proud to direct them to the new look and feel of the GEOSS portal, where an intuitive interface means that their data can be discovered and accessed with ease.'

Improving the portal was made possible by portal public–private partnerships with geolocation software developers *Google Maps, what3words* and *ESRI*.

ESA has been the official GEOSS portal provider since 2012, in cooperation with the *Italian National Research Council's Institute for Atmospheric Pollution Research* (CNR-IIA) and the *GEO Discovery and Access Broker*. In response to user needs, work to improve the portal began in 2016.

> 'The fruitful cooperation with ESA is important and benefits the whole GEOSS community, in particular for better informed decision-making, said Nicola Pirrone, director of CNR-IIA.

ESA plans to continue developing the portal with *CNR-IIA* and the *GEO Secretariat* to render it more user-friendly. Activities will also be coordinated with other ESA initiatives like the Thematic Exploitation Platforms and the latest European Earth observation ground segment evolution strategy.

> 'This cooperation between ESA and the EC in GEO is of strategic importance, and I expect that such a key European contribution to GEO will maximise the benefits of Earth observations to society through effective partnerships within GEO,' said Robert-Jan Smits, GEO co-chair and Director General of the European Commission General Directorate for Research and Innovation.

TBS-5927

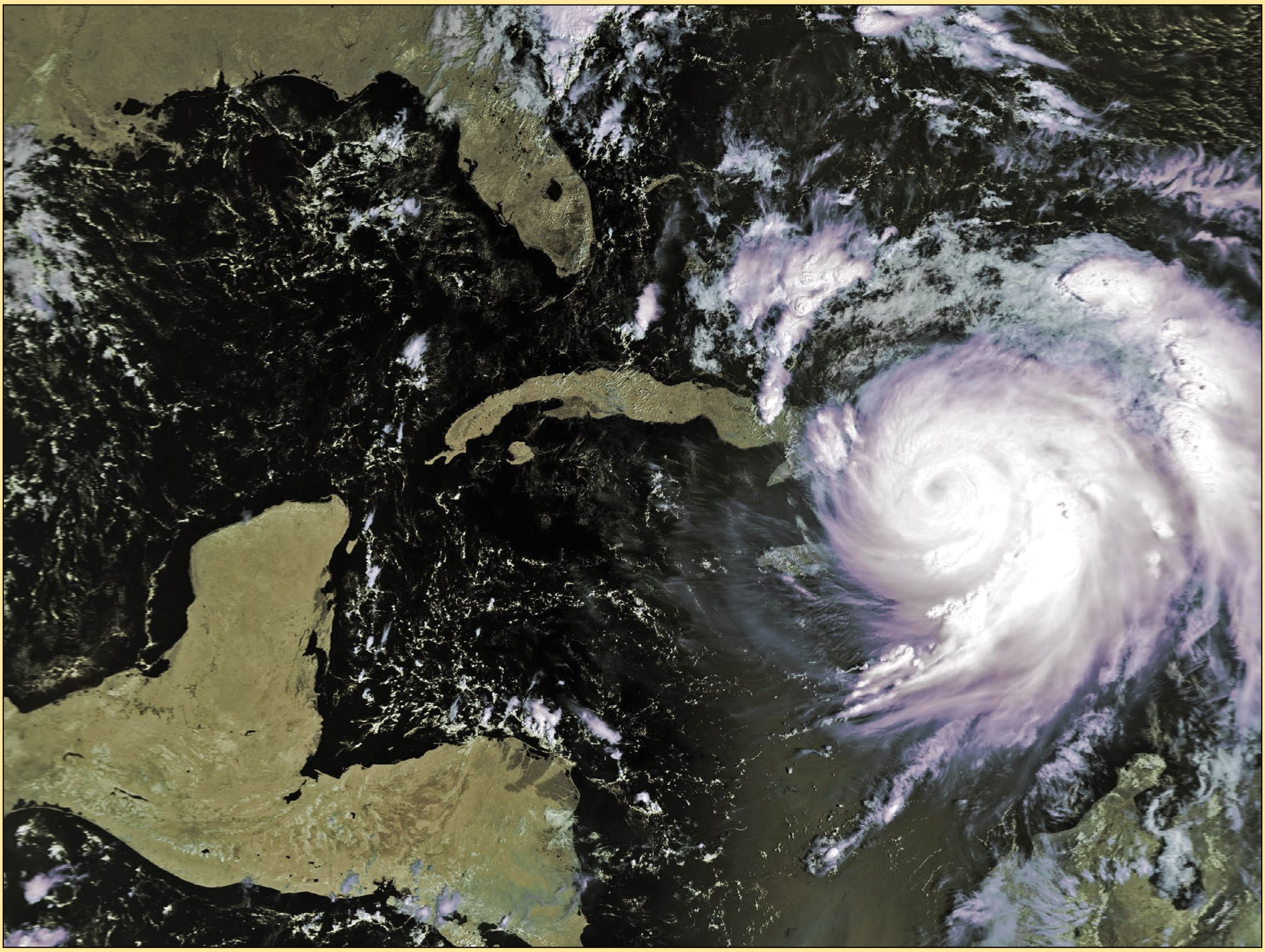
Professional USB DVB-S2-Tuner

Mike Stevens

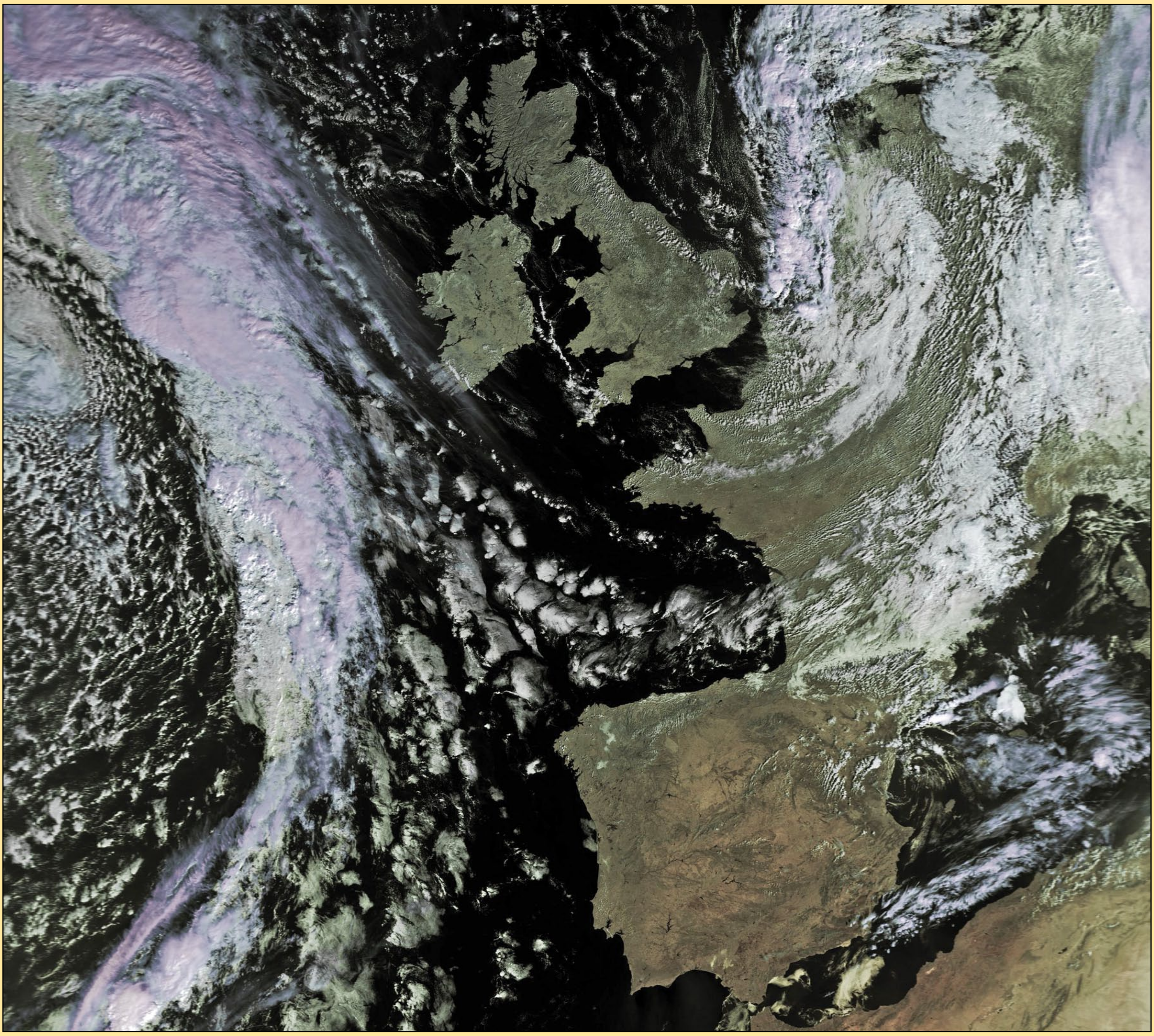
I have recently been testing a new tuner from our friends in the Far East, the TBS-5927. This is, a more advanced version of the TBS-5925—the original USB unit—now upgraded with the same successful CY-68013 chip-demodulator as is fitted to the excellent TBS-6903 PCIe card tuner. This chip has already proved to be an excellent, stable, demodulator when installed within the TBS-6903, itself is a very reliable tuner for EUMETCast reception.

The TBS-5927 interfaces with the PC via a USB connection, power is supplied by 12-volt adaptor, and the tuner supports only one LNB connection. An early problem relating to the stability of the tuner has now been overcome by the inclusion of an internal cooling fan, which prevents it overheating. The TBS-5927 has proved to have excellent front-end gain, is very selective with extreme sensitivity and is very stable. I started testing this tuner in July 2016 and have it running 24/7 without any problems. It has completely new driver software and also new TBS-IP Data software (version 3.0.5.0), which I also have been using very successfully on both Windows 8.1 and Windows 10, the latter still performing extremely well even following *Microsoft's Anniversary Upgrade*.

The TBS-5927 USB DVB-S2 Tuner



This Metop-B image featuring Hurricane Matthew east of Cuba was received with the TBS-5927 on October 4, 2016.
Image © EUMETSAT 2016



This Metop-B image was received with the TBS-5927 on October 2, 2016.
Image © EUMETSAT 2016

As this is a USB tuner, I am sure it will appeal to members who do not like tampering with the internal workings of their computers. You just have to plug it into a USB 2.0 socket: it's that simple! The Tuner measured 100 × 85 × 20 mm: so small and neat. The TBS-5927, which is a DVB-S2 Single Tuner, has *EUMETCast* compatibility, and is able to receive ACM/VCM, supports *Multi-Input Stream* and is able to handle the *High-Speed Data* satellite stream. I can confirm that its *EUMETCast* capabilities are very good and, during the test period, when I experienced some rather inclement weather with strong winds and some heavy rain with thunderstorms, the tuner still performed immaculately. During heavy rain SNR was 9.8, missed packets before FEC was 9 and with FEC Recovered at 9. Under those conditions this was not at all disappointing, but under normal conditions it's zero all-round with no segment loss.

Software Installation is the same as for all TBS tuners. Install the correct driver and the *dpinst x86/64* file (depending on whether your operating system is 32/64 bit). Those of you who are already using TBS tuners will be familiar with the installation procedure: new users who are not should not find it difficult. As always, the first step is to create a separate 'Tools' folder directly on the 'C:\' drive (and not in the Program Files(x86) folder) then, within the Tools folder, a folder called 'TBS Software': install all TBS software in this folder, following all on-screen prompts.

There are many members willing to help, myself included. Also, if you have back copies of GEO Quarterly, you can refer to numerous articles I have written about TBS software installation, which are listed below.

So there we have it, another DVB-S2 TBS USB Tuner for *EUMETCast* reception of weather related data. It's an amazing bit of kit that will work well as a main tuner or as a spare for back-up. Happy weather watch from Portland.

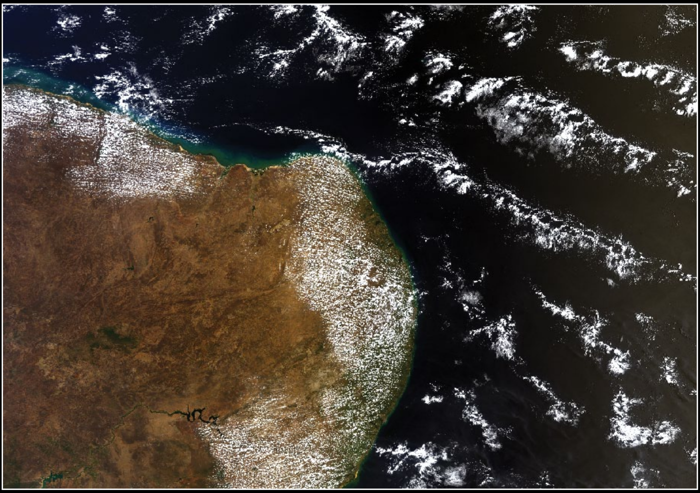
References

- Testing the TBS 6925 Tuner Card for EUMETCast
  GEO Quarterly 42, page 16
- Setting up the TBS-6925 Tuner Card for EUMETCast
  GEO Quarterly 43, page 13
- Testing the TBS 6983 and HD DVB S2 Tuner Cards
  GEO Quarterly 46, page 34
- The TBS 6908 DVB S2 Tuner
  GEO Quarterly 48, page 6
- EUMETCast Reception with the TBS-6903 Tuner
  GEO Quarterly 49, page 34

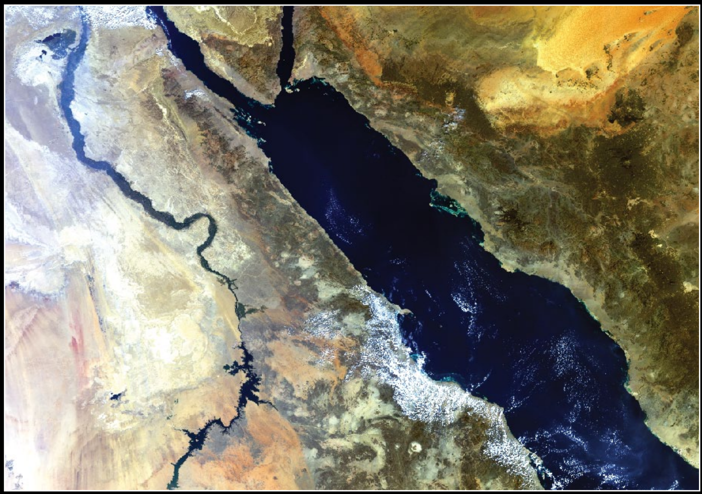
Sentinel-3A Showcase

Mike Stevens

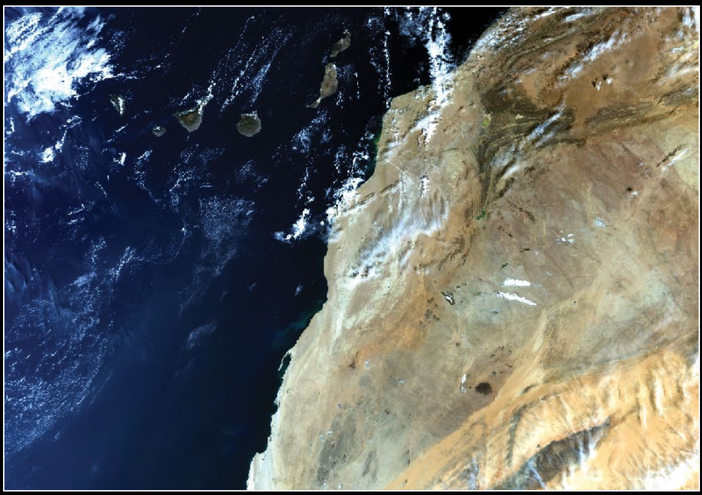
At the moment I am receiving image segments from complete north to south passes of Sentinal-3A using my TBS-6903 Tuner, but have no way to join them together. David Taylor is working on joining software to combine these segments, along the general style of his *Metop Manager*. I'm also hoping that Hugo Van Ruyskensvelde will soon add this capability to his EUMETCastView software. Although individual segments measure just 917 × 640 pixels, they nevertheless demonstrate the 300 metres/pixel resolution of this satellite to perfection.



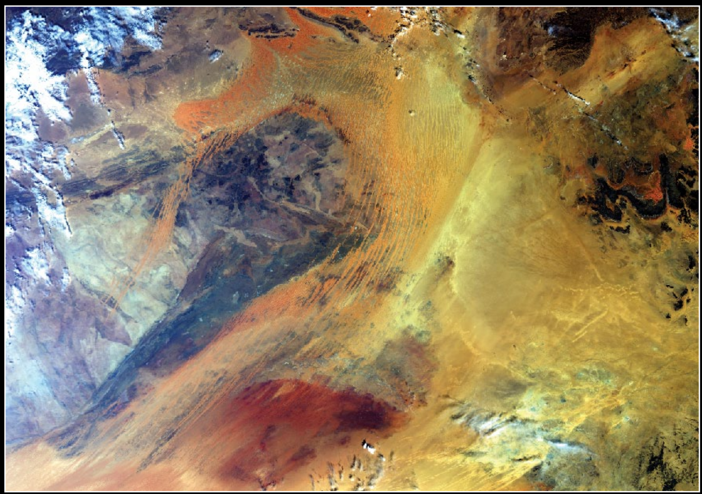
Northeast Brazil - October 27
Image © EUMETSAT 2016



Red Sea and River Nile - October 29
Image © EUMETSAT 2016

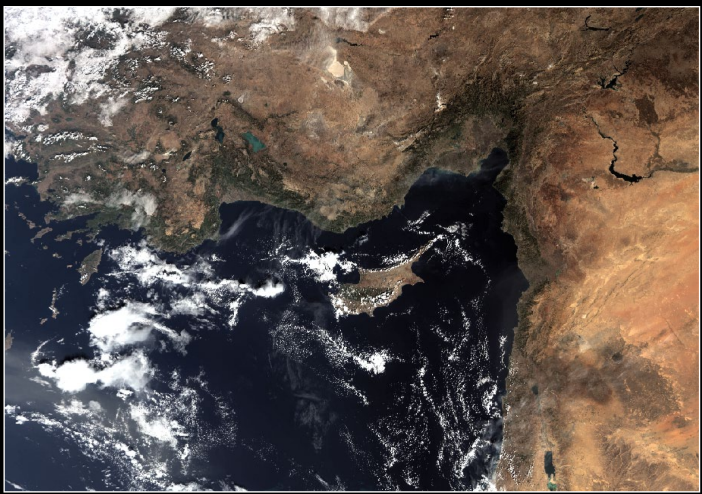


The Canary Islands and Morocco - November 2
Image © EUMETSAT 2016



Detail from the Sahara Desert - October 27
Image © EUMETSAT 2016

The Persian Gulf and Gulf of Oman - November 5
Image © EUMETSAT 2016



Turkey, Cyprus and eastern Mediterranean - November 5
Image © EUMETSAT 2016

A Curious Ensemble of Wonderful Features

NASA Earth Observatory

When John Wesley Powell explored the Colorado River in 1869, he made the first thorough survey of one of the last blank spots on the map. The expedition began in May at Green River, Wyoming and ended three months later at the confluence of the Colorado and Virgin Rivers in present-day Nevada.

About two months into their journey, the nine men of the expedition found themselves in Glen Canyon. As the men travelled along the serpentine river channel, they encountered what Powell later described in *Canyons of Colorado* as "a curious ensemble of wonderful features."

While the walls were not nearly as high in Glen Canyon as they were downstream in Marble Canyon or Grand Canyon, the explorers encountered a labyrinth of overhanging cliffs, hanging gardens, sweeping river bends, and natural arches set amidst a backdrop of colourful buttes and mesas.

'Past these towering monuments, past these mounded billows of orange sandstone, past these oak-set glens, past these fern-decked alcoves, past these mural curves, we glide hour after hour, stopping now and then, as our attention is arrested by some new wonder,' wrote Powell.

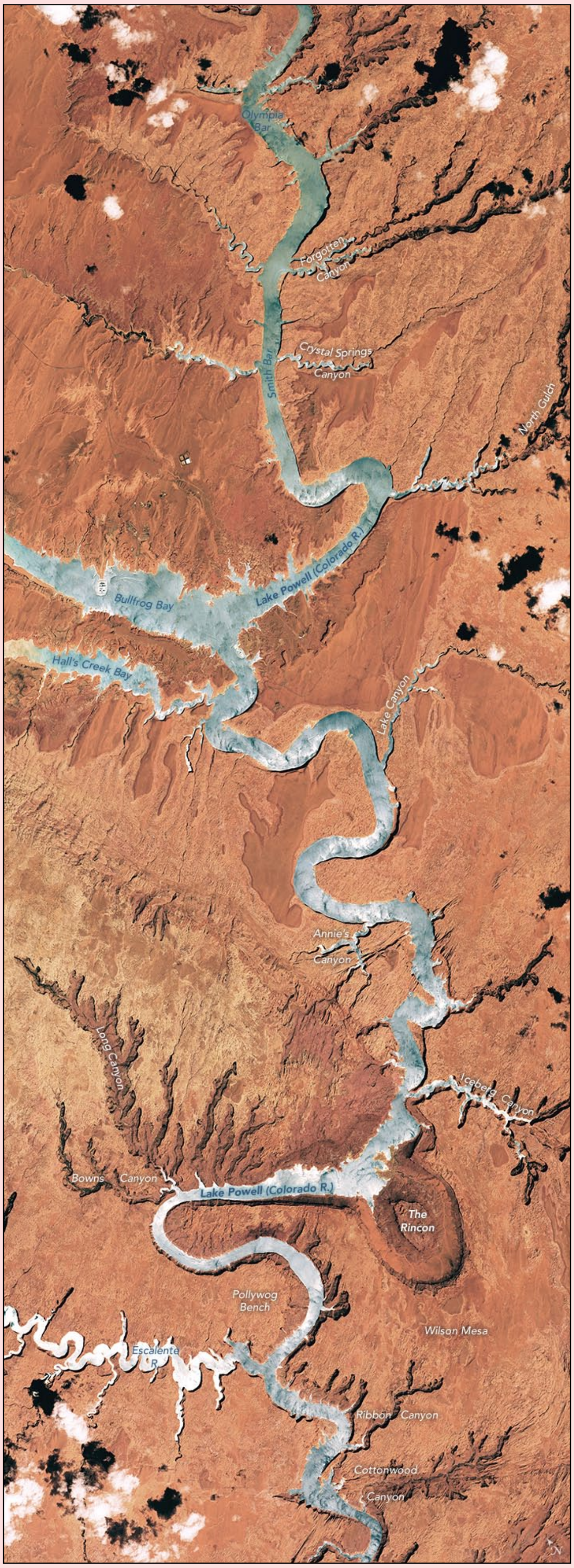
From above, the view of Glen Canyon is equally arresting. In 2016, an astronaut aboard the International Space Station took several photographs that were combined to make this long mosaic. The water has an unnatural shade of blue because of sunglint, an optical phenomenon that occurs when sunlight reflects off the surface of water at the same angle as a camera views it.

One of the most prominent features in this stretch of the Colorado is the Rincon, an entrenched and abandoned meander—or loop—in the river. Geologists believe it formed several thousand years ago when the river cut straight across the ends of the loop and shortened its course by 10 kilometres.

The modern view is rather different to what members of Powell's expedition would probably have seen. When the Glen Canyon Dam was finished in 1963, water levels began a slow rise, submerging many of the geological features—including an acoustically remarkable side canyon called Music Temple—that Powell found so compelling. Due to drought and the presence of porous rock in this area, it a took a full 17 years for the reservoir (Lake Powell) to reach its maximum capacity.

Wikipedia - Music Temple

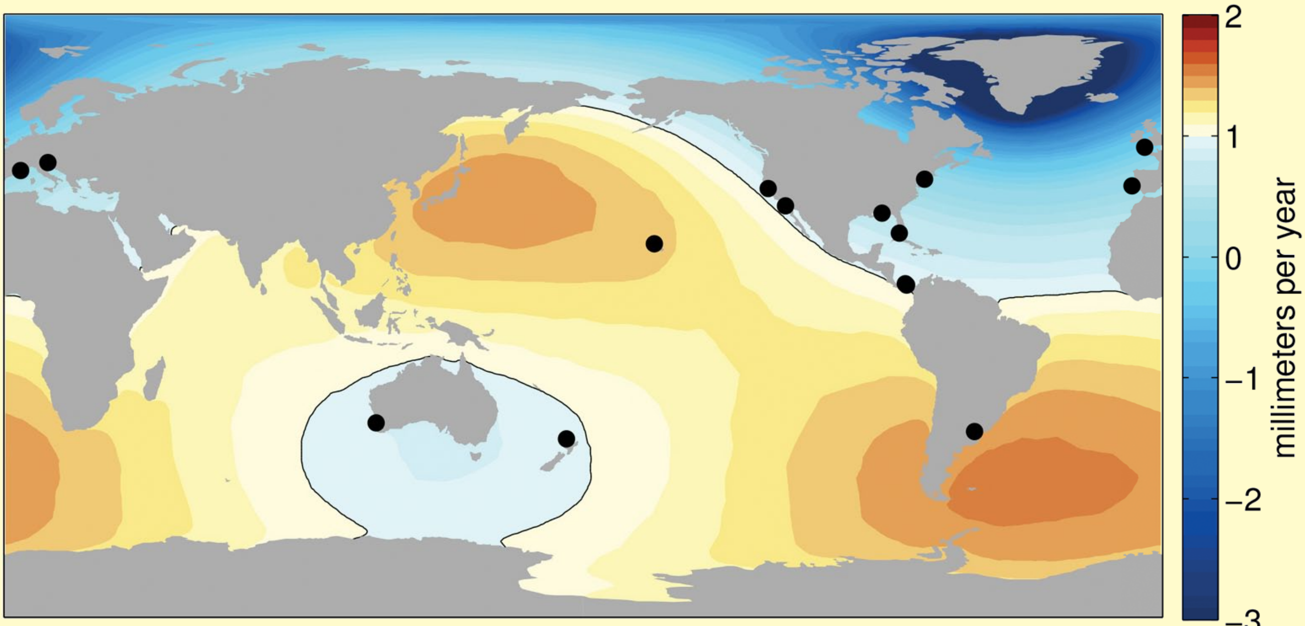
Music Temple was a geological feature near the Colorado River in Glen Canyon, southern Utah, which consisted of a grotto with high, vaulting walls and a deep central pool of water. John Wesley Powell named it "Music Temple" because of its unusual acoustic properties: reportedly, a one-second note would reverberate for eleven seconds. It was considered one of the more beautiful natural formations of the area in the late 19th century and into the mid-20th century but following construction of Glen Canyon Dam in the early 1960s, Music Temple was became submerged by Lake Powell and disappeared as the lake filled.



This mosaic was assembled from photographs taken from the International Space Station. A version of it was posted here. Caption by Adam Voiland.

Historical Records May Underestimate Sea Level Rise

Climate.nasa.gov News



Fingerprint of Greenland Ice Melt

Sea level change resulting from Greenland ice melt, derived from NASA GRACE measurements. Black circles show locations of the best historical water level records, which underestimate global average sea level rise due to Greenland melt by about 25 percent.
Credit: University of Hawaii/NASA-JPL/Caltech.

A new NASA and university study using NASA satellite data finds that tide gauges—the longest and highest-quality records of historical ocean water levels—may have underestimated the amount of global average sea level rise that occurred during the 20th century.

A research team led by Philip Thompson, associate director of the University of Hawaii Sea Level Center in the School of Ocean and Earth Science and Technology, Manoa, evaluated how various processes that cause sea level to change differently in different places may have affected past measurements. The team also included scientists from NASA's Jet Propulsion Laboratory, Pasadena, California, and Old Dominion University, Norfolk, Virginia.

> *'It's not that there's something wrong with the instruments or the data,' stated Thompson, 'but for a variety of reasons, sea level does not change at the same pace everywhere at the same time. As it turns out, our best historical sea level records tend to be located where 20th century sea level rise was most likely less than the true global average.'*

One of the key processes the researchers looked at is the effect of 'ice melt fingerprints', which are global patterns of sea level change caused by deviations in Earth's rotation and local gravity that occur when a large ice mass melts. To determine the unique melt fingerprint for glaciers, ice caps and ice sheets, the team used data from NASA's *Gravity Recovery and Climate Experiment* (GRACE [1]) satellites on Earth's changing gravitational field, and a novel modelling tool (developed by study co-author Surendra Adhikari and the JPL team) that simulates how ocean mass is redistributed due to ice melting.

One of the most fascinating and counter-intuitive features of these fingerprints is that sea level drops in the vicinity of a melting glacier, instead of rising as might be expected. The loss of ice mass reduces the glacier's gravitational influence, causing nearby ocean water to migrate away. But far from the glacier, the water it has added to the ocean causes sea level to rise at a much greater rate.

During the 20th century, the dominant locations of global ice melt were in the Northern Hemisphere. The results of this study showed that many of the highest-quality historical water level records are taken from places where the melt fingerprints of Northern Hemisphere sources result in reduced local sea level change compared to the global average. Furthermore, the scientists found that factors capable of enhancing sea level rise at these locations, such as wind or Southern Hemisphere melt, were not likely to have counteracted the impact of fingerprints from Northern Hemisphere ice melt.

The study concludes it is highly unlikely that global average sea level rose less than 14 centimetres during the 20th century. The most likely amount was closer 17 centimetres.

> *'This is really important, because it provides answers to the question about how melt fingerprints and the influence of wind on ocean circulation affect our ability to estimate past sea level rise,' said Thompson. 'These results suggest that our longest records are most likely to underestimate past global mean change and allow us to establish the minimum amount of global sea level rise that could have occurred during the last century.'*

Results are published in *Geophysical Research Letters*. To read the full paper, visit:

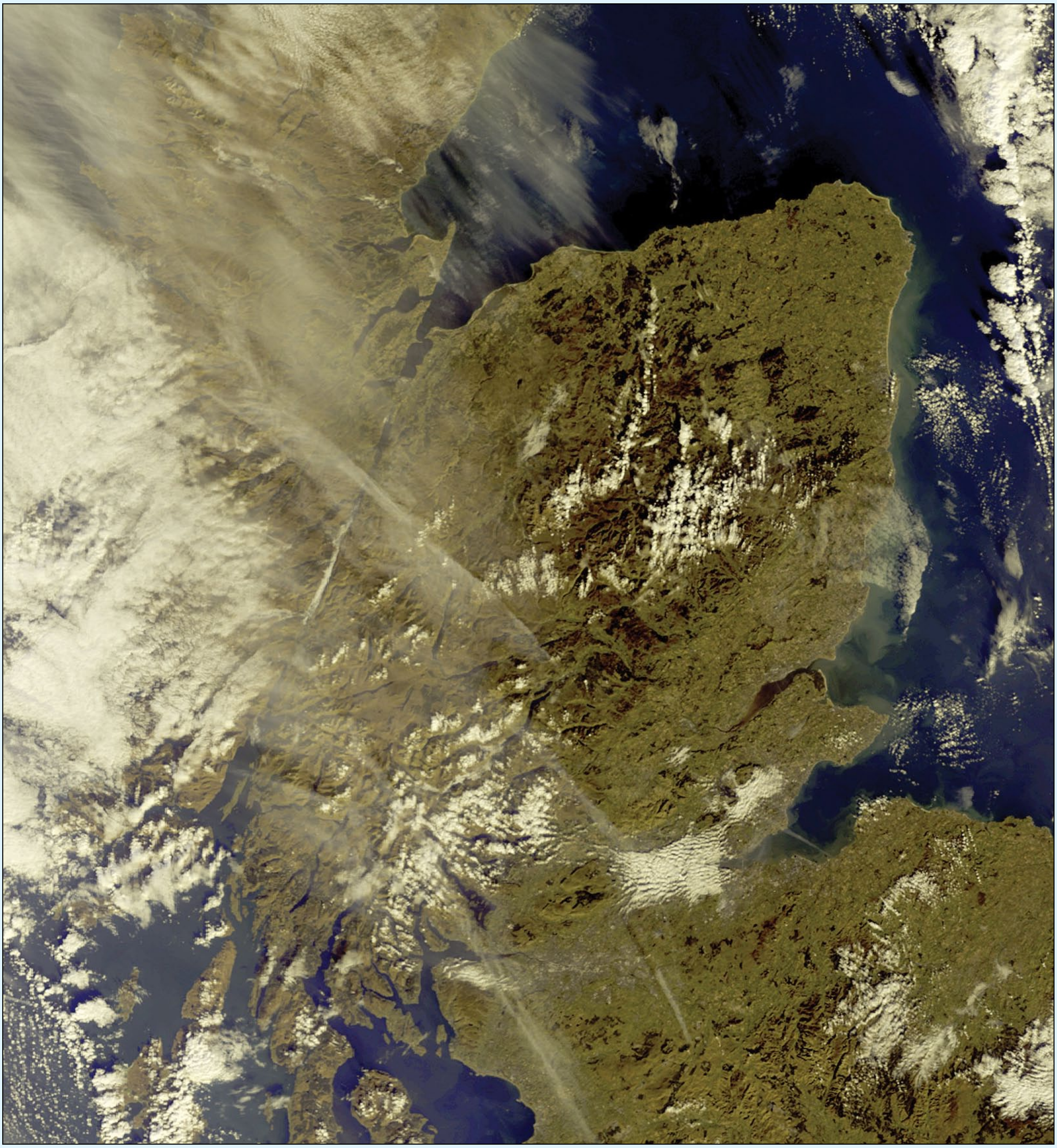
http://onlinelibrary.wiley.com/doi/10.1002/2016GL070552/abstract

Reference

1 GRACE is a joint NASA mission with the German Aerospace Center (DLR) and the German Research Center for Geosciences (GFZ), in partnership with the University of Texas at Austin. For more information on the mission, visit:

First HVS/Sentinel-3A Data

David Taylor



On October 25, 2016, I received my first Sentinel 3A data, resulting in the stunning image of Scotland reproduced above, on which you can clearly see the Forth Road Bridge, a feature indistinguishable in NOAA/Metop HRPT data.

The data is part of the *EUMETCast High Volume Service* (HVS) which started this year. Anyone with a EUMETCast system can get access to the HVS which carries Sentinel-3A data at a resolution of 300 metres/pixel, but you do need a good signal which may mean an 85 cm dish in southern England or a 1 metre dish in Scotland. Once you have acquired the files—roughly 600 Mb for 3-minute segment—you will require ESA's *Sentinel Application Platform* (SNAP) software for processing. It can be downloaded from

http://step.esa.int/main/download/

I post-processed this image from SNAP in *Paintshop Pro* to tweak the levels and sharpen it a little. 300 metres/pixel.

Swanning Around in Space

Francis Bell

For about two years the International Space Station (ISS) has been carrying out the *High Definition Earth Viewing* (HDEV) experiment using HD Colour TV cameras, and my interest in this relates to the Earth images which are being transmitted live from the ISS. There are four cameras in this experiment, one giving a forward view of the ISS's flight path, two providing rear views, and the fourth, which is my favourite, giving a vertical view towards Earth.

The transmissions from the ISS alternate between these cameras and it can be difficult to predict which camera may be in use at any one time. There is regular switching between cameras, plus intervals when there are no images—perhaps for communication reasons. Also, of course, for half of every orbit, the ISS will be in darkness: so no worthwhile images are available.

Notwithstanding the above limitation about available images, I have been intermittently viewing these transmissions since the early days of the experiment and occasionally record an image which I find particularly attractive. Very often I am attracted to images which show easily recognisable geographical or meteorological features. Images from these cameras are constantly available from the following website

http://www.ustream.tv/channel/iss-hdev-payload

With a little experience of using this site you can display live full screen images from the HD TV cameras—but remember that orbital position, sunlight and communication links vary, so eye-catching images are not available all the time. Figures 1,2 and 3 show examples of views from the forward looking camera, the rear view camera and the vertical camera.

Figure 1 - This is a screen-shot recorded in mid 2016 showing a forward, slightly to the right, southern view of South Africa. The Cape of Good Hope is towards the centre right of the image with much of the land mass of South Africa appearing cloudless.

Figure 2 - This is a view to the rear looking south and slightly to the west. The peninsula of Baja California can be seen on the right together with the Gulf of California, with the right hand side showing part of mainland Mexico and part of southern USA.

Figure 3 - This is a near vertical image showing an almost cloudless view of the Straight of Gibraltar, with part of mainland Spain to the lower right and some of Morocco shown at upper left.

The Cygnus Automatic Cargo Spacecraft

In addition to the website listed above, there is another website used by NASA for transmitting HD TV. The attraction for me of this additional channel is that it often shows views inside the ISS and also carries sound. I have listened and watched this channel before and sometimes heard radio exchanges during space walks and other events inside the ISS. To receive this channel go to this website

http://www.nasa.gov/multimedia/nasatv/iss_ustream.html

Quite by chance, at about 09.30 UT on October 25, 2016, I logged into this channel to view the ISS transmissions and was astonished with the first images I saw. Instead of the unobstructed view of Earth's surface which I was expecting, the foreground showed a space vehicle close to the ISS. Not quite understanding what was happening, I started to save some of these surprising views coming from the ISS. However, it was the voice comments in the background which revealed to me what was happening.

Apparently, a few days previously, a cargo module

Figure 4 - The *Cygnus* module, caught by the HD TV Earth viewing camera. Comments from NASA ground control indicated the module to be about 100 m from the ISS. Rather surprisingly, the module's docking port seems to be located at the complex end of the module as seen on the left of the image.

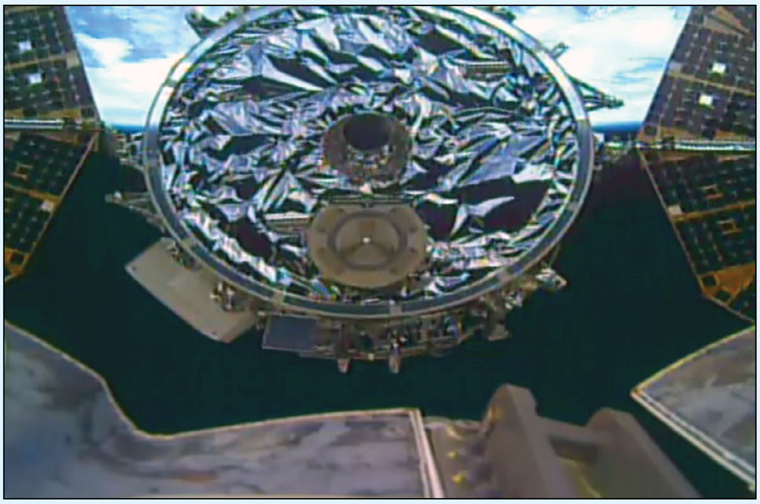


Figure 5 - This shot shows the *Cygnus* module within a very few metres of the ISS, where it remained for some minutes while the docking arms on the ISS were activated.

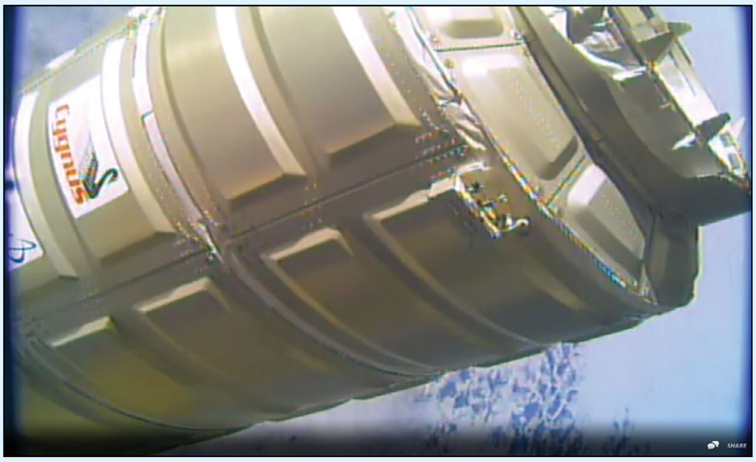


Figure 6 - This is a close-up of the Cygnus cargo module after docking with the ISS.

called *Cygnus* (as is swan) had been launched from a Russian site to ferry two and a half tonnes of food and equipment to the ISS. It so happened that I was watching and listening to the final few minutes of the manoeuvring and final docking of this cargo vehicle to the ISS.

Listening to the ground control comments, I hadn't realised just how precise the docking and timings had to be. When I first saw *Cygnus* it was reported to be about 80 metres from the ISS, but it was then manoeuvred into a precise holding position 30 m away for about 20 minutes while docking protocols were confirmed. From the voice commentary I was surprised to learn that the final docking only had a window of opportunity of about 20 minutes. The docking was achieved while the ISS was flying above Kurdistan, which I guess was because direct radio communication was then possible between the ISS and Russian ground stations, thus making direct commands possible without the need to relay through other systems.

Docking was achieved at 10.25 UT or, interestingly quoted by the voice link I was listening to, 6.25 USA Central Time.

Conclusion

The point of this article is to encourage those interested to access the websites quoted above and follow the activities on the ISS. Any individual, school or other group with access to a computer and an Internet link can follow the many interesting live transmission from the ISS. For my part I will be more attentive to times when there are space walks and other dockings to the ISS.

Figure 7 - This image includes part of the ISS's main structure, and it's believed that it shows the docking area for the Cygnus automatic cargo spacecraft. The background shows a substantial coastal boundary on Earth's surface

Image: NASA.

Vancouver Island

John Tellick

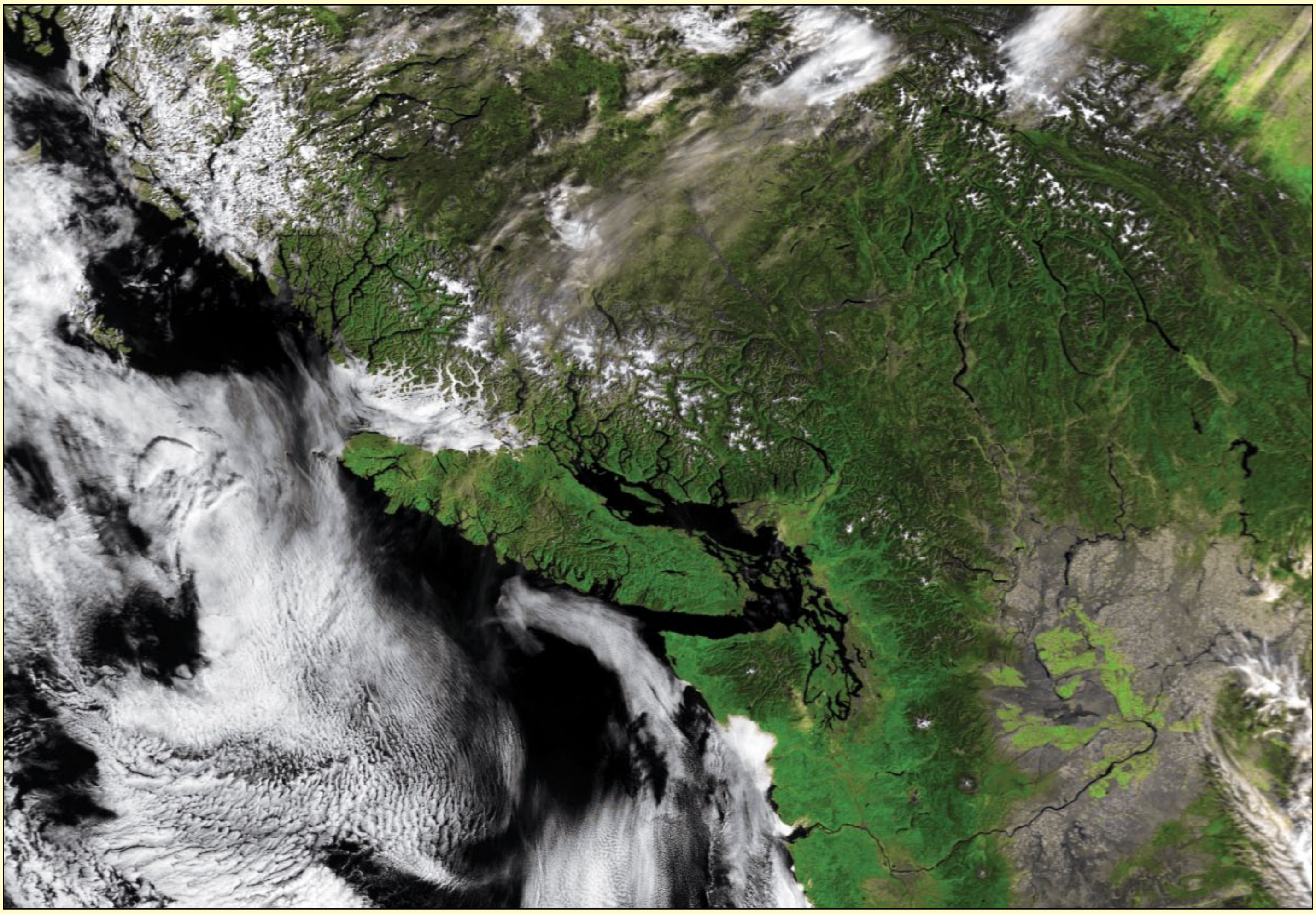
Vancouver Island is located in the northeastern Pacific Ocean, just off the coast of Canada, and is part of the Canadian province of British Columbia. The island is 460 kilometres long, 100 kilometres at its widest point, and has an area of 32,134 km^2. It is the largest island on the West Coast of North America.

The southern part of Vancouver Island is the only part of British Columbia or Western Canada to lie south of the 49^{th} Parallel, along with most of the southern Gulf Islands and minor offshore islands. This area has one of the warmest climates in Canada, and since the mid-1990s has been mild enough in a few areas to grow subtropical Mediterranean crops such as olives and lemons.

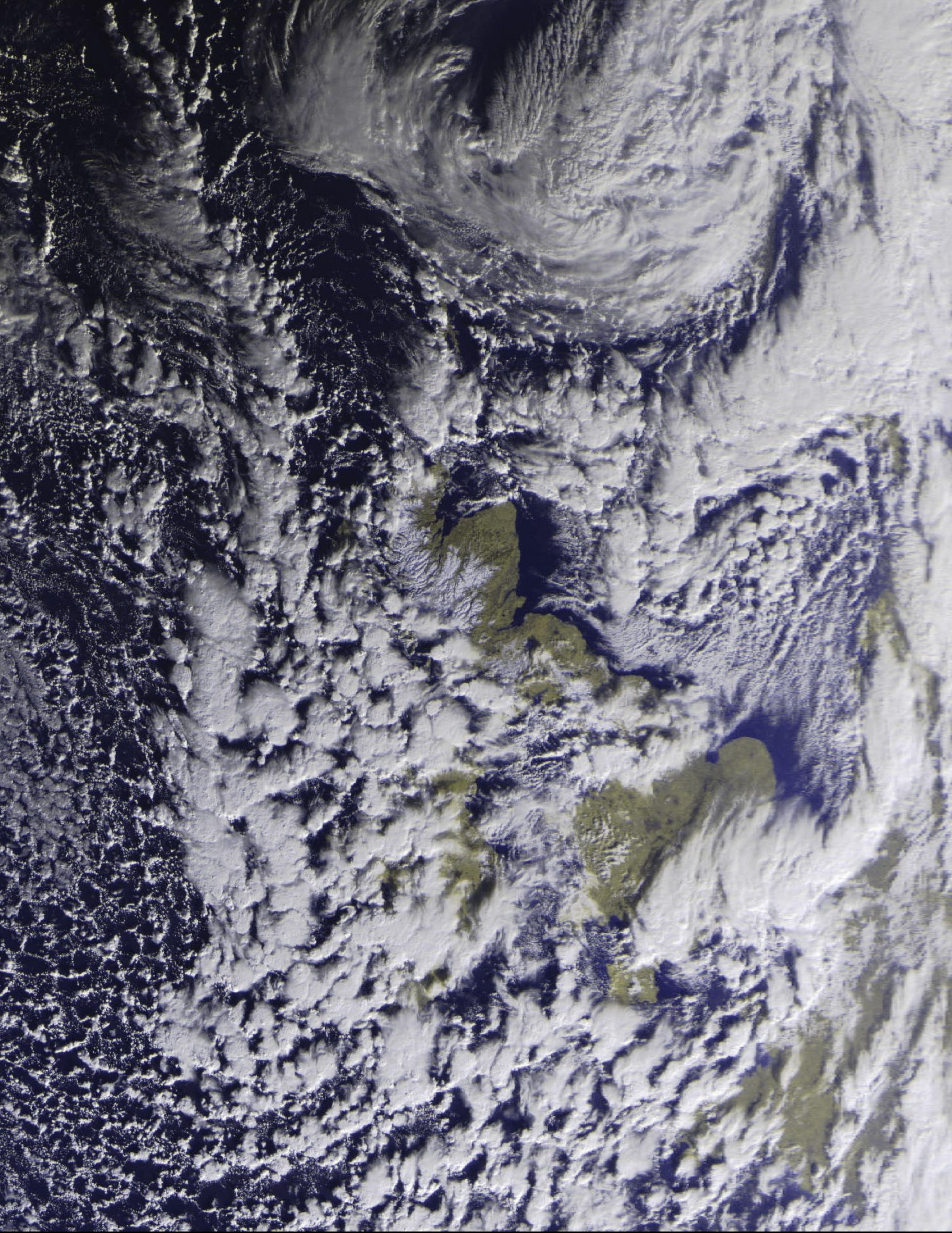
Victoria, the capital city of British Columbia, is located on the island, but the larger city of Vancouver is not—it stands on the North American mainland, across the Strait of Georgia from Nanaimo.

Vancouver Island has been the homeland to many indigenous peoples for thousands of years. The island was explored by British and Spanish expeditions in the late 18^{th} century, and was originally named *Quadra's and Vancouver's Island* in commemoration of the friendly negotiations held during the Nootka Crisis in 1792 by Spanish commander of the Nootka Sound settlement, Juan Francisco de la Bodega y Quadra, and by British naval captain George Vancouver. Quadra's name was eventually dropped from this appellation. The island is one of several North American locations named after George Vancouver, who explored the Pacific Northwest coast between 1791 and 1794.

Vancouver Island is the world's 43^{rd} largest island, Canada's 11^{th} largest island, and Canada's second most populous one after the Island of Montreal. It is the largest Pacific island anywhere east of New Zealand.



This image of the northwest coast of Canada was taken by Metop-B on September 14, 2016, and includes a detailed view of Vancouver Island.
Image © EUMETSAT 2016 - Processed in vegetation mode with David Taylor's HRPT Reader



Winter hit Scotland hard starting on November 18, 2016 when polar air streamed south over the country producing contrasting effects. In the west, a sequence of snow showers blanketed the highlands of the west and northwest, but in the northeast it heralded a spell of clear skies with temperatures dropping as low as minus 10°C overnight and remaining close to zero during the days.
Image © EUMETSAT 2016

This amazing image detailing the Alps and the Mediterranean islands of Corsica and Sardinia is a short segment taken from a huge pole-to-pole image from an NPP-Suomi pass downloaded via EUMETCast by Mike Stevens on November 6, 2016.
Image © EUMETSAT 2016

GEO Outreach

Visit to the Kempton Rally

Francis Bell

I think it's important to promote GEO at educational and other events such as amateur radio rallies and other events with a technical interest: otherwise these groups may be unaware of GEO and the ability to receive satellite signals directly from space. With this perspective in mind I try to attend appropriate events, sometimes demonstrating live satellites reception but always with a display of recorded images and appropriate literature. I'm always pleased with the response of visitors to our GEO stands. Even after brief conversations they get useful information and it raises the profile of GEO.

I note that this may be an appropriate time to attend as many of these events as we can because of the interest in space science created by Tim Peake's recent six months on the ISS. Certainly, schools and amateur radio groups have been stimulated, perhaps to the point where they would like to try satellite reception for themselves. This is an opportunity for any GEO member to support their local community by promoting talks, demonstrations and exhibitions demonstrating satellite reception. GEO will support any such opportunity, so please respond to this idea and promote GEO within your own local groups. Contact the GEO management team if you need help.

Recently GEO has attended the AMSAT-UK three day colloquium, The 'Space Link' educational one day event for schools, the Alton Scouts 'Thinking day on the Air' plus the 'South London Radio and Computer Rally' at Kempton.

The amateur radio station and GEO's stand at the Alton Scouts **Thinking Day on the Air**. We are pictured here while live on air, waiting for the arrival of the scouts, some together with their families, in October 2016.

Kempton

It was a pleasure to run our GEO stand again this autumn at the *South London Radio and Computer Rally* held at Kempton, SW London. We have regularly attended these twice-yearly rallies almost since the formation of GEO over ten years ago. It has always been a rewarding experience because of the positive feedback we receive from those visiting our stand. During the weekend, we met a delightful nine year old girl who had recently become a licensed radio amateur, and who has used her communication skills regularly on the mountains of the Lake District. With a substantial age difference, another notable visitor was a gentleman whose job it was to design commercial satellite ground stations.

On this occasion we ran demonstrations of recorded polar orbiting satellite images together with the latest *EUMETCast* images and their animated sequences. We also demonstrated the ability of the SDR dongle (which we had for sale on the stand) to receive a wide range of radio signals, including tracking the local aircraft as well as polar orbiting satellites.

New memberships were recorded together with renewals and the literature we had available on the stand was gratefully acknowledged by the visitors. My thanks to David Simmons for attending the rally with me.

If you have an event in your area, then please consider offering the organisers some contribution from GEO. It would be great if you could report to the Editor any contributions you may have which promotes GEO.

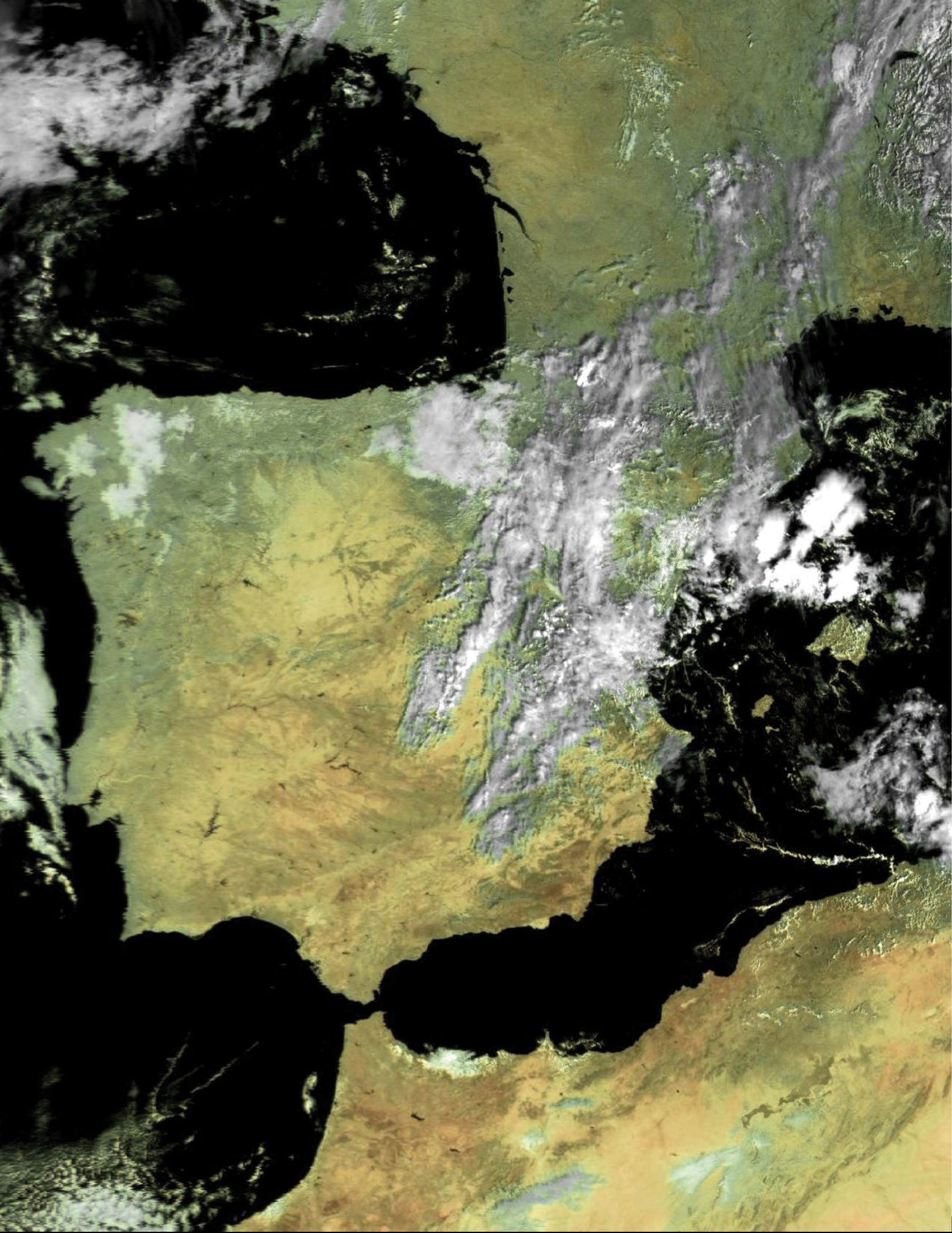
Delegates and families visiting the exhibition room close to GEO's exhibition stand during The AMSAT-UK colloquium in July 2016.

Fifteen year old Jessica Leigh (far right, seated) and her friend Polly Gupta, both from Sandringham School, are pictured visiting the amateur radio station at the AMSAT-UK colloquium 2016. Jessica spoke to Tim Peake on the ISS via a scheduled radio link.

Visitors of all ages examining the NOAA APT slide show running on one of the three demonstration computers we had available on the GEO stand at the busy Kempton Rally, November 2016

A knowledgeable visitor talking to David Simmons at the GEO stand at the Kempton Rally. Visitors in the background indicate how busy and worthwhile the day was for GEO.

Examining GEO Quarterly magazines during the AMSAT-UK Colloquium: could this youngster be a potential GEO Member for the future?



This is a section from a Meteor M2 LRPT image acquired from the 09:26 UT pass on September 23, 2016 by Enrico Gobbetti.

Quarterly ? Question Extra

Francis Bell

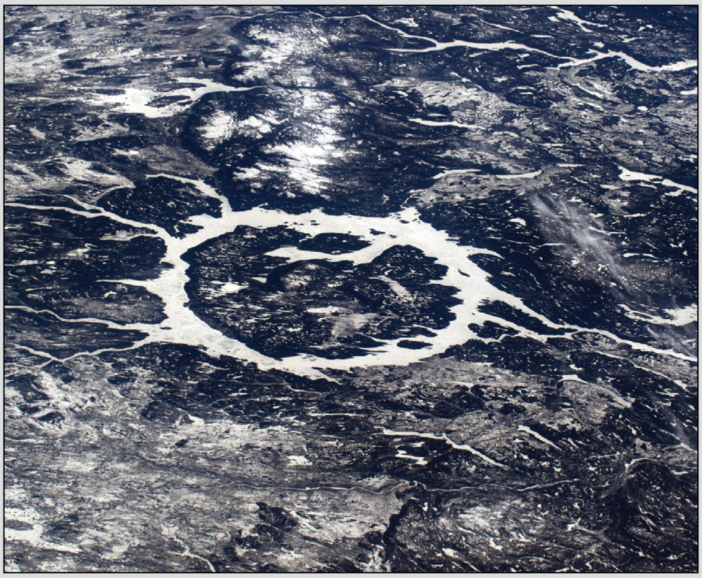


Figure 1 - This photograph was taken by Tim Peake during his stay aboard the International Space Station.

When drafting Quarterly Questions I often pick a subject which for whatever reason has recently caught my attention. Sometimes this can be a technical issue but often relates to an eye-catching satellite image of the Earth.

Now here comes a major coincidence - or are there others in the world just like me? Tim Peake while on the ISS for six months took many photograph with his own camera and some of these photographs have been released to the public. There is a special collection of Tim's ten favourite photographs which attracted my attention and I have archived some of these for my own collection.

I was recently browsing through these photographs when I noticed an overlap with GEO Quarterly Question images and two of Tim Peake's photographs which exactly matched our Quarterly Questions 50 and 52. These photographs are shown in Figures 1 and 2. Recognising the coincidence with GEO Quarterly Questions it's up to the reader to identify the areas of the Earth which Tim photographed. Just as a guide note that Figure 1 photograph shows an image about 30 km wide while in Figure 2 the width is about 200 km.

Other photographs in Tim Peake's top ten photographs include Istanbul, the UK, Italy at night, the Sinai Peninsula with the Dead Sea, Grand Canyon USA, Scotland by day and a detailed view of New York. There is a huge selection of photographs of Earth on Tim Peake's *Flickr* site at

https://www.flickr.com/photos/timpeake/albums/72157660209464584

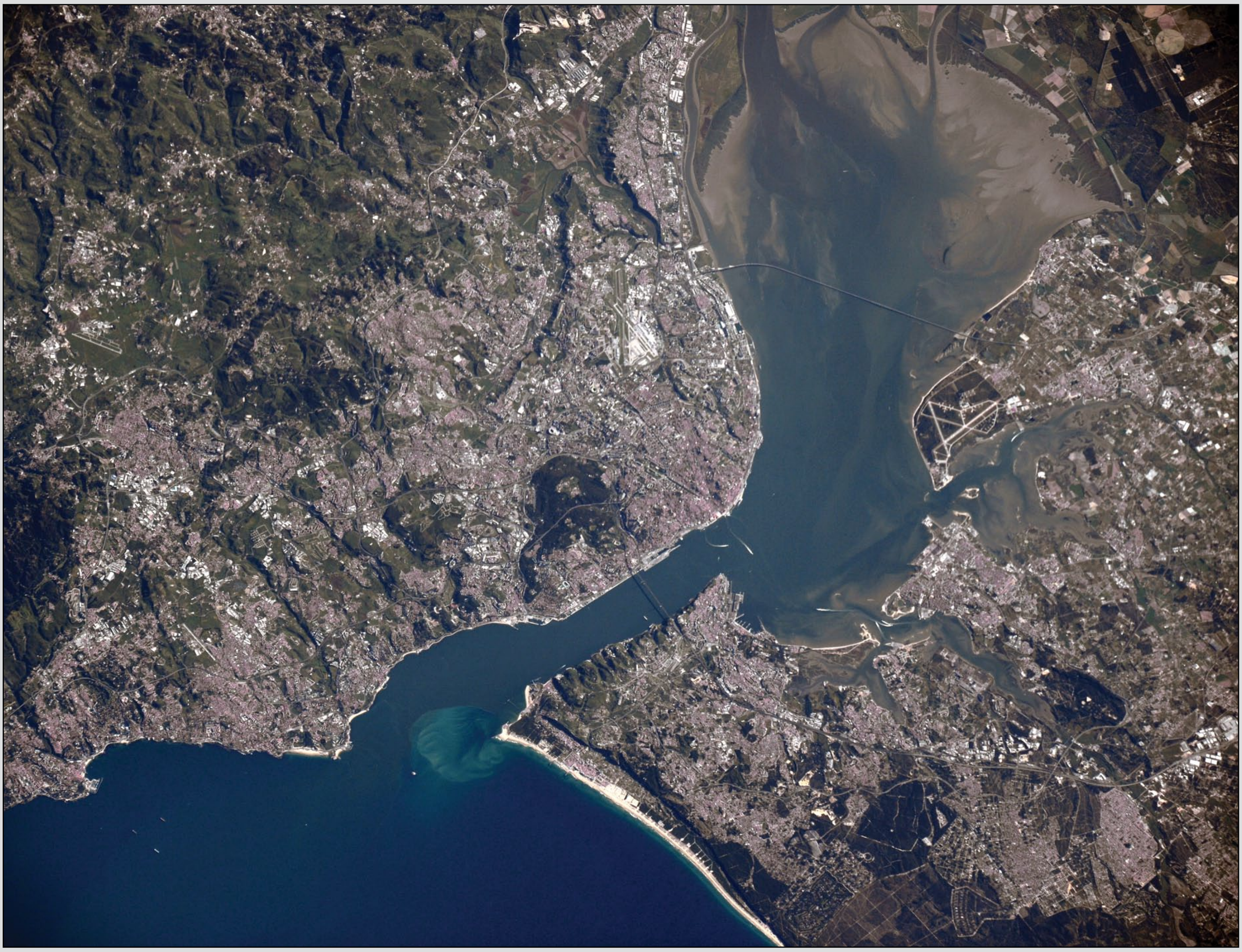
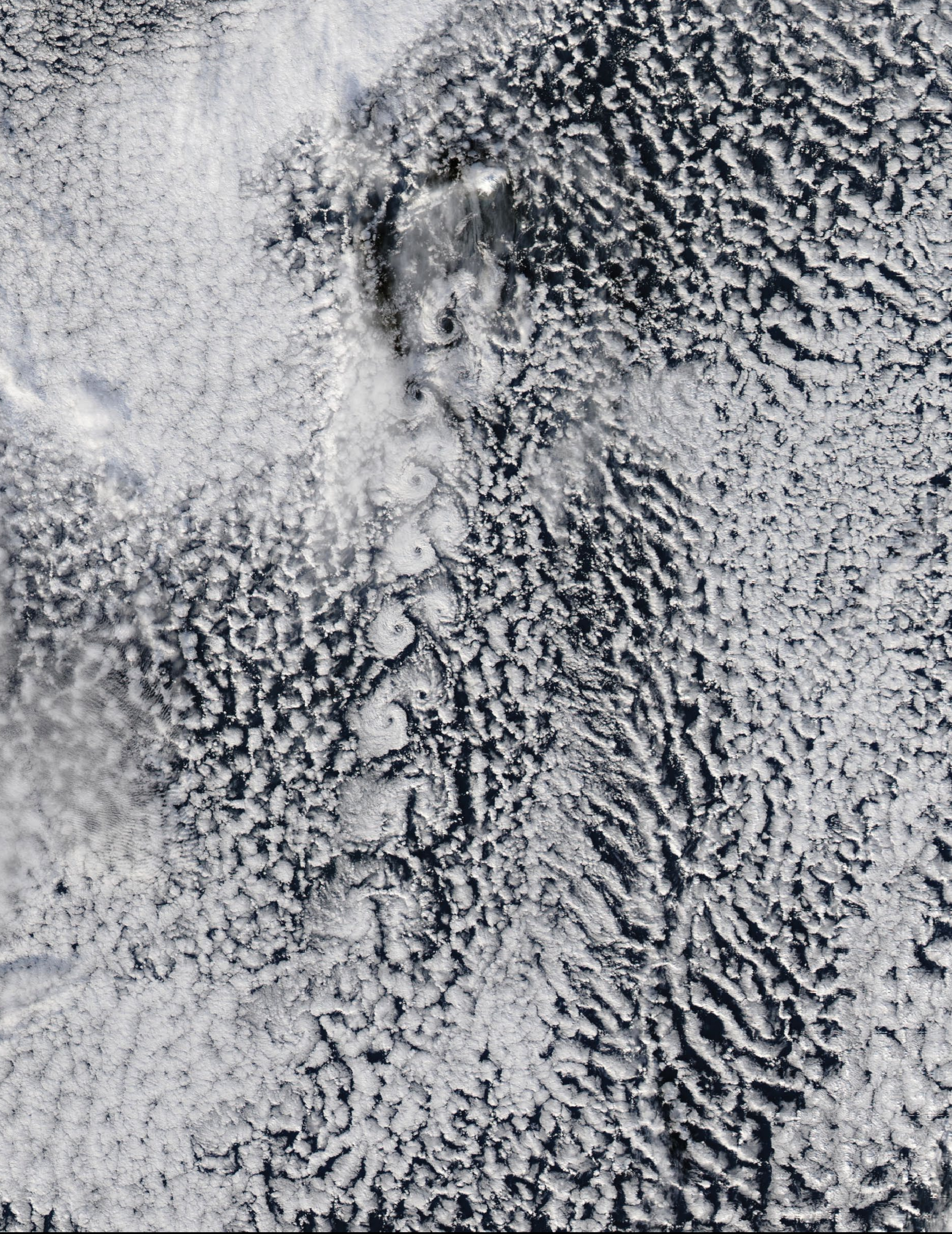
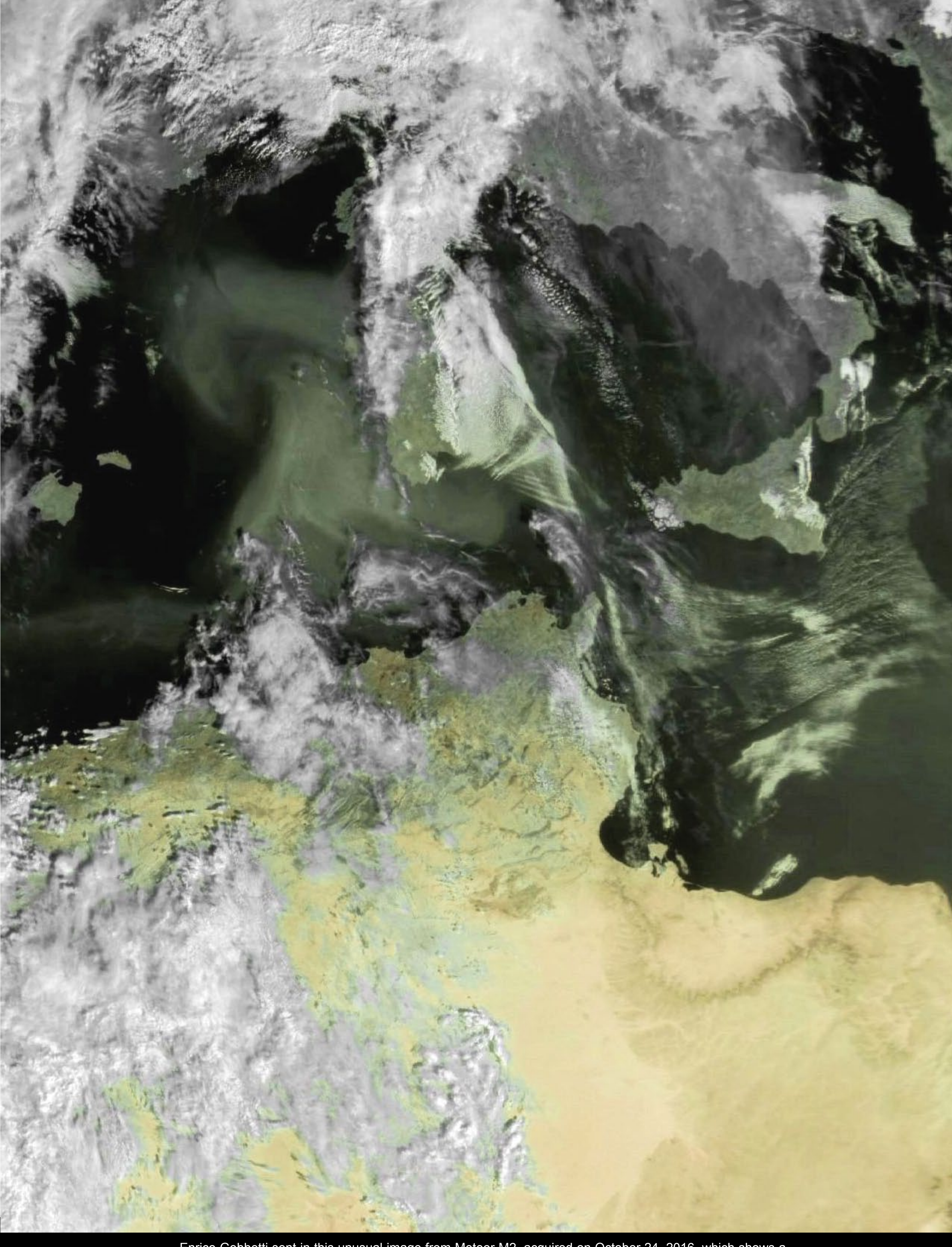


Figure 2 - This photograph was taken by Tim Peake during his stay aboard the International Space Station.



The MODIS instrument aboard NASA's Aqua satellite captured this scene detailing a fine set of Von Karman vortices shedding from Jan Mayen Island, in the North Atlantic.on September 30, 2016.
Image: LANCE Rapid Response/NASA/GSFC



Enrico Gobbetti sent in this unusual image from Meteor M2, acquired on October 24, 2016, which shows a dust storm from the Algerian Sahara blowing across the Mediterranean Sea towards Sardinia.

Seeing Equinoxes and Solstices from Space

continued from page 17

On March 20 and September 20, the terminator is a vertical north-south line, and the Sun is sits directly above the equator. On December 21, the Sun resides directly over the Tropic of Capricorn when viewed from the ground, and sunlight spreads over more of the Southern Hemisphere. On June 21, the Sun sits above the Tropic of Cancer, spreading more sunlight in the north and turning the tables on the south. The bulge of our spherical Earth blocks sunlight from the far hemisphere at the solstices; that same curvature allows the Sun's rays to spread over a greater area near the top and bottom of the globe.

Of course, it is not the Sun that is moving north or south through the seasons, but a change in the orientation and angles between the Earth and its nearest star. The axis of the Earth is tilted 23.5° relative to the Sun and the ecliptic plane. The axis is tilted away from the Sun at the December solstice and toward the Sun at the June solstice, spreading more and less light on each hemisphere. At the equinoxes, the tilt is at a right angle to the Sun and the light is spread evenly.

Equinox means 'equal night' in Latin, capturing the idea that daytime and nighttime are equal lengths everywhere on the planet. That is true of the Sun's presence above the horizon, though it does not account for twilight, when the Sun's rays extend from beyond the horizon to illuminate our gas-filled atmosphere.

You can view a day-by-day Meteosat animation of the process described above on NASA's website at

http://earthobservatory.nasa.gov/IOTD/view.php?id=52248

Cover Image Details

Front Cover

This detailed image segment depicting part of the Red Sea, with the River Nile to its west, comes from a Sentinel-3A frame downloaded via EUMETCast by Mike Stevens. You can view a full version of this image, and several more of Mike's Sentinel-3A imagesa on page 33.

Image © EUMETSAT 2016

Inside Front Cover

David Taylor provided this HRPT image of a splendid sunny day in the British Isles on September 22, 2016, the result of a ridge of high pressure between depressions, as captured by NOAA 19's 14:06 UT pass, via EUMETCast.

Image © EUMETSAT 2016

Inside Back Cover

Hurricane Matthew, at one point a Category-5 storm, imaged by NASA's Terra satellite on October 2, 2016, as it headed towards Haiti and Cuba.

Image: LANCE Rapid Response/NASA/GSFC

Back Cover (upper)

Enrico Gobbetti submitted this Meteor-M2 image stretching from the eastern Mediterranean Sea to the Caspian and Aral Seas, acquired from the 06:50 UT pass on October 6, 2016.

Back Cover (lower)

Peter Kooistra sent in this Meteor-M2 image showing a plume of sand being blown towards Crete from Libya on November 5, 2016.

Climate Change: How do we know?

continued from page 14

Extreme Events

The number of record high temperature events in the United States has been increasing, while the number of record low temperature events has been decreasing, since 1950. The US has also witnessed increasing numbers of intense rainfall events.

Ocean Acidification

Since the beginning of the Industrial Revolution, the acidity of surface ocean waters has increased by about 30%. This increase is the result of humans emitting more carbon dioxide into the atmosphere and hence more of this gas being absorbed into the oceans. The quantity of carbon dioxide absorbed by the upper layer of the oceans is increasing by about 2 billion tons per year.

Decreased Snow Cover

Satellite observations reveal that the amount of spring snow cover in the Northern Hemisphere has decreased over the past five decades and that the snow is melting earlier.

Acknowledgement and Further Reading

The text of this article has been reproduced from the website of the *Earth Science Communications Team* at NASA's Jet Propulsion Laboratory/California Institute of Technology. The original content can be found at

http://climate.nasa.gov/evidence/

The web article concluded with a comprehensive list of sixteen references to original sources of information presented, and these are well worth exploring by anyone interested in Climate Change.

References

1 Intergovernmental Panel on Climate Change https://www.ipcc.ch/
2 In the 1860s, physicist John Tyndall recognised the Earth's natural greenhouse effect and suggested that slight changes in the atmospheric composition could bring about climatic variations. In 1896, a seminal paper by Swedish scientist Svante Arrhenius first speculated that changes in the levels of carbon dioxide in the atmosphere could substantially alter the surface temperature through the greenhouse effect.
3 Gravity Recovery and Climate Experiment http://www.nasa.gov/mission_pages/Grace/

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 [1]
Meteor M N1	137.0968 MHz	Off	Dead? [7]
Meteor M N2	137.1000 MHz	On	Good

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	---	AHRPT	[2]
Feng Yun 3B	1704.5 MHz	---	AHRPT	[2]
Feng Yun 3C	1704.5 MHz	---	AHRPT	[2]
Metop A	1701.3 MHz	RHCP	AHRPT	Good
Metop B	1701.3 MHz	RHCP	AHRPT	Good
Meteor M N1	1700.00 MHz	RHCP	AHRPT	Dead? [7]
Meteor M N2	1700.0 MHz	RHCP	AHRPT	Good

Geostationary Satellites				
Satellite	Transmission Mode(s)		Position	Status
Meteosat 7	HRIT 1691 MHz / WEFAX 1691 MHz		57.5°E	On
Meteosat 8	HRIT (digital)	---	3.5°E	Standby [3]
Meteosat 9	HRIT (digital)	LRIT (digital)	9.5°E	On [4]
Meteosat 10	HRIT (digital)	LRIT (digital)	0°W	On
GOES-13 (E)	GVAR 1685.7 MHz	LRIT 1691.0 MHz	75°W	On [5]
GOES-14	GVAR 1685.7 MHz	LRIT 1691.0 MHz	105°W	Standby
GOES-15 (W)	GVAR 1685.7 MHz	LRIT 1691.0 MHz	135°W	On [5]
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	86.5°E	Off [6]
Feng Yun 2E	SVISSR	LRIT	104.0°E	On
Feng Yun 2F	SVISSR	LRIT	112.0°E	On
Feng Yun 2G	SVISSR	LRIT	86.5°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 operational backup satellite
4 Meteosat Rapid Scanning Service (RSS)
5 GOES 13 and GOES 15 also transmit EMWIN on 1692.70 MHz
6 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.
7 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.

EUMETCast On-Line Registration Guide

If you require to register as a first-time user for any of the free EUMETCast data streams such as MSG, NOAA AVHRR, Metop etc., or need to renew an existing subscription, this must be done on-line.

GEO has produced a step-by-step guide to the entire process at

http://www.geo-web.org.uk/eumreg.php

This guide also contains a direct link to the official EUMETCast on-line registration form, which can otherwise prove somewhat tricky to locate.

Weather Satellite Reports

If there is a single Internet Forum that is relevant to all weather satellite enthusiasts, it must surely be Douglas Deans' Weather Satellite reports.

Here you will find every conceivable type of information about weather satellites, whether polar or geostationary, APT, HRPT, LRIT, EUMETCast or whatever.

Absolutely everything is covered, and the information is updated every week. Special additional bulletins may be issued if an important change takes place mid week.

You can read the bulletins from this URL

https://groups.yahoo.com/neo/groups/weather-satellite-reports/info

or, even better, elect to have the reports sent to you by email every Monday.

Internet Discussion Groups

There are a numerous Internet-based discussion groups of interest to weather satellite enthusiasts. The home page for each group provides an email address through which you can request membership. Even a blank email containing the word 'subscribe' in its Subject line is all that is required.

APT Decoder

This is a group where users of Patrik Tast's APTDecoder can share information and problems.

https://groups.yahoo.com/neo/groups/APTDecoder/info

GEO-Subscribers

This is GEO's own group, where members can exchange information and post queries relating to any aspect related to weather satellite reception (hardware, software, antennas etc), Earth observation satellites and any GEO-related matter.

https://groups.yahoo.com/neo/groups/GEO-Subscribers/info

Satsignal

An end-user self-help group for users of David Taylor's Satellite Software Tools (SatSignal, WXtrack, GeoSatSignal, HRPT Reader, GroundMap, MSG Data Manager, AVHRR Manager and the ATOVS Reader).

https://groups.yahoo.com/neo/groups/SatSignal/info

MSG-1

A forum dedicated to Meteosat Second Generation (MSG), where members share information about the *EUMETCast* reception hardware and software.

https://groups.yahoo.com/neo/groups/MSG-1/info

GEO Helplines

Douglas Deans, Dunblane, Scotland.

All aspects of weather satellites from APT, HRPT to Meteosat-9 DVB/EUMETCast systems.

- telephone:(01786) 82 28 28
- e-mail: dsdeans@btinternet.com

John Tellick, Surrey, England.

Meteosat advice: registering for the various MSG services, hardware and software installation and troubleshooting. John will also field general queries about any aspect of receiving weather satellite transmissions.

- telephone: (0208) 390 3315
- e-mail: info@geo-web.org.uk

Geoff Morris, Flintshire, NE Wales.

Geoff has lots of experience with aerial, coax connectors, mounting hardware etc. and has also done a lot of work with the orbiting satellites. Geoff has been a EUMETCast Meteosat user for some time and is familiar with David Taylor's MSG software. He should be able to share his experiences with newcomers to this branch of the hobby.

- Tel: (01244) 818252
- e-mail: gw3atz@btopenworld.com

Mike Stevens, Dorset, England.

Assistance with reception of EUMETCast to include Metop-A and Metop-B; also MSG Data reception and set-up within the PC, assistance with dish alignment and set-up, and installation and set-up of TBS DVB-S2 units.

- email: mikeg4cfz@gmail.com

Guy Martin, Kent, England.

Guy is prepared to advise anyone who wishing to receive MSG/Metop using Windows 2000 or XP. Can also help with networking and ADSL router setup.

- gmartin@electroweb.co.uk

Hector Cintron, Puerto Rico, USA.

Hector is prepared to field enquiries on HRPT, APT, EMWIN and NOAAPORT

- Phone: 787-774-8657
- e-mail: n1tkk@hwic.net

Email contact can of course be made at any time, but we would ask you to respect privacy by restricting telephone contact to the period 7.00 - 9.00 pm in the evenings.

Copy for GEO Quarterly

Original contributions relating to any aspect of Earth Imaging should be submitted in electronic format (although handwritten and typed copy will be accepted).

Please note that **major articles** which contain a large number of illustrations should be submitted **as early as possible before copy deadline**, to give time for preparation prior to publication.

Please note that it is preferred that satellite images are provided **without added grid lines, country outlines or captions** unless these are considered essential for illustrative purposes in an accompanying article.

Submission of Copy

Materials for publication should be sent to the editor,

Les Hamilton
8 Deeside Place
Aberdeen AB15 7PW
Scotland

The most efficient way to do this is by **email attachments** to the following address

geoeditor@geo-web.org.uk

Particularly large attachments (8 MB and above) can be transmitted via *Hightail*

https*://wwwhightail.com/*

Group for Earth Observation

Membership Application Form

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Commencing May 1, 2016, your £15 Membership Fee will cover two years

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This will bring you 4 electronic (PDF) GEO Quarterlies each year
You will also be mailed a *printed copy* of the December issues

You can make your 2-year GEO Membership payment by any of the following methods:

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- UK residents may pay by means of a **personal cheque** or **Postal Order** made payable to '*Group for Earth Observation*'
- Payment by **direct bank transfer** can be arranged. Please email ***members@geo-web.org.uk*** for BIC and IBAN details.

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Country

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FAX

Email Address (please print very clearly)

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I wish to join GEO, the Group for Earth Observation, for a period of two years.

I sign below to confirm that I have no objection to my membership details being held on a computer database and understand that these details will be used *exclusively* for internal GEO administraton purposes.

Signature

Date

Your subscription is valid for two years from your date of application and entitles you to all the privileges of membership of the Group for Earth Observation, including four issues of GEO Quarterly. Please note that your subscription will commence with the issue of GEO Quarterly that is current at the time of your application. Back issues, where available, may be ordered from the GEO Shop.

Please send your completed form to:
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35 Sycamore Road,
East Leake
Loughborough LE12 6PP, UK

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Loughborough LE12 6PP
England, UK.

If you prefer not to remove this page from your Quarterly, a photocopy or scan of this Membership Form is perfectly acceptable

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GEO Shop

Manager: Nigel Evans
email: geoonlinestore@gmail.com

For our full range, visit GEO Shop at

http://www.geo-web.org.uk/shop.php

Ayecka-SR1 DVB-S2 VCM USB Receiver

This advanced DVB-S2 VCM Receiver has been extensively tested by both EUMETSAT and GEO, and has proved to be exceptionally suitable for trouble-free reception of the EUMETCast DVB-S2 transmissions that became standard from the start of 2015.

The price includes a USB cable, wall power supply, shipping and *Paypal* fees.

UK members price - £375.00
EU members price - £385.00

Current Price List

	Members' Prices			Prices for non-Members		
	UK	EU	RoW	UK	EU	RoW
Ayecka SR1 DVB-S2 Receiver	375.00	385.00	390.00	---------	---------	---------
Edimax USB 2.0 Fast Ethernet Adapter	15.00	17.00	18.00	---------	---------	---------
DVB-S USB 2102 Receiver	60.60	67.00	---------	70.60	77.00	---------
SDR Dongle kit for APT/LRPT	20.00	25.00	26.00	---------	--------	--------
Technisat Satfinder Alignment Meter	26.50	29.50	---------	29.50	32.50	---------
GEO Quarterly Back Issues (subject to availability)	3.80	4.60	5.60	n/a	n/a	n/a
GEO Quarterly (PDF on CD) 2004-2014 (Annual compilations - state year)	8.00	8.80	9.30	n/a	n/a	n/a
GEO Membership (4 PDF magazines and one printed magazine per year)	15.00	15.00	15.00	15.00	15.00	10.00

All prices are in £ sterling and include postage and packaging

NEWSKY RTL2832U/R820T2 SDR DAB USB MCX Socket Special Dongle

for reception of NOAA APT and Meteor M2 LRPT

- Frequency range: (*100) 700 kHz - 1864 MHz
- MCX Socket
- Active Crystal Oscillator
- Reinforced Socket

This stick does not come with SDR software or instructions.

UK members price - £20.00
EU members price - £25.00

TechniSat SatFinder Antenna Alignment Meter

This sensitive meter is a great help in setting up and aligning the dish for maximum signal. The meter comes with full instructions.

UK members price - £26.50
UK non-member's price - £29.50

Ordering and Shipping

We will ship by post, so please allow a few days for items to arrive in Europe and perhaps a few weeks for the Rest of the World.

Orders should be sent by email to

geoonlinestore@gmail.com

or made through the GEO Website at

http://www.geo-web.org.uk/shop.php

Goods are normally shipped within 28 days, subject to availability.

Not yet a GEO Member?

GEO can provide most of the items advertised (with the exception of GEO Quarterly back-issues and CDs) to both members and non members: but non-members cannot benefit from the discounted members prices.

Why not join GEO and take advantage of the discounted prices we can offer you as a member?

Annual Subscription Rate for all regions in now £15 (UK)

For this you will receive 4 electronic (PDF) copies of GEO Quarterly Magazine. In addition, you will be mailed **a printed version** of the December magazine.

GEO Quarterly - Back Issues

(Only available to GEO Members)

Paper copies of back issues of GEO Quarterly may be available, but it is advisable to check before ordering.

UK members price - £3.80

Annual compilations of GEO Quarterly back issues in PDF format are available on CD. Be sure to state the year of each annual compilation that you wish to order.

UK members price - £8.00

Inverto-Black-Ultra High-Performance LNBs

GEO currently recommends these LNBs for EUMETCast reception. We are currently **not stocking** this item but it is available at ***Amazon***.

http://www.amazon.co.uk/gp/product/B001ONAEKI/

Twin LNB 40mm 0,2dB £15.50
Single satellite LNB £ 9.95

Edimax USB 2.0 Fast Ethernet Adapter

This adapter enables you to add a *second* network connection for your PC/Laptop, to connect to the Ayecka SR1 Traffic port, thereby relieving loading on the home network. Typically, you would assign this adapter with an IP address on the same network as the SR1 i.e 192.168.10.103. Data from the SR1 passes directly to the PC whilst its internet connection remains on your usual home network 192.168.1.xxx (Management Port).

UK members price - £15.00
UK non-members price - £17.00