

# DIY Open Weather Workshop



Concept by/ Konzipiert von  
Sasha Engelmann & Sophie Dyer

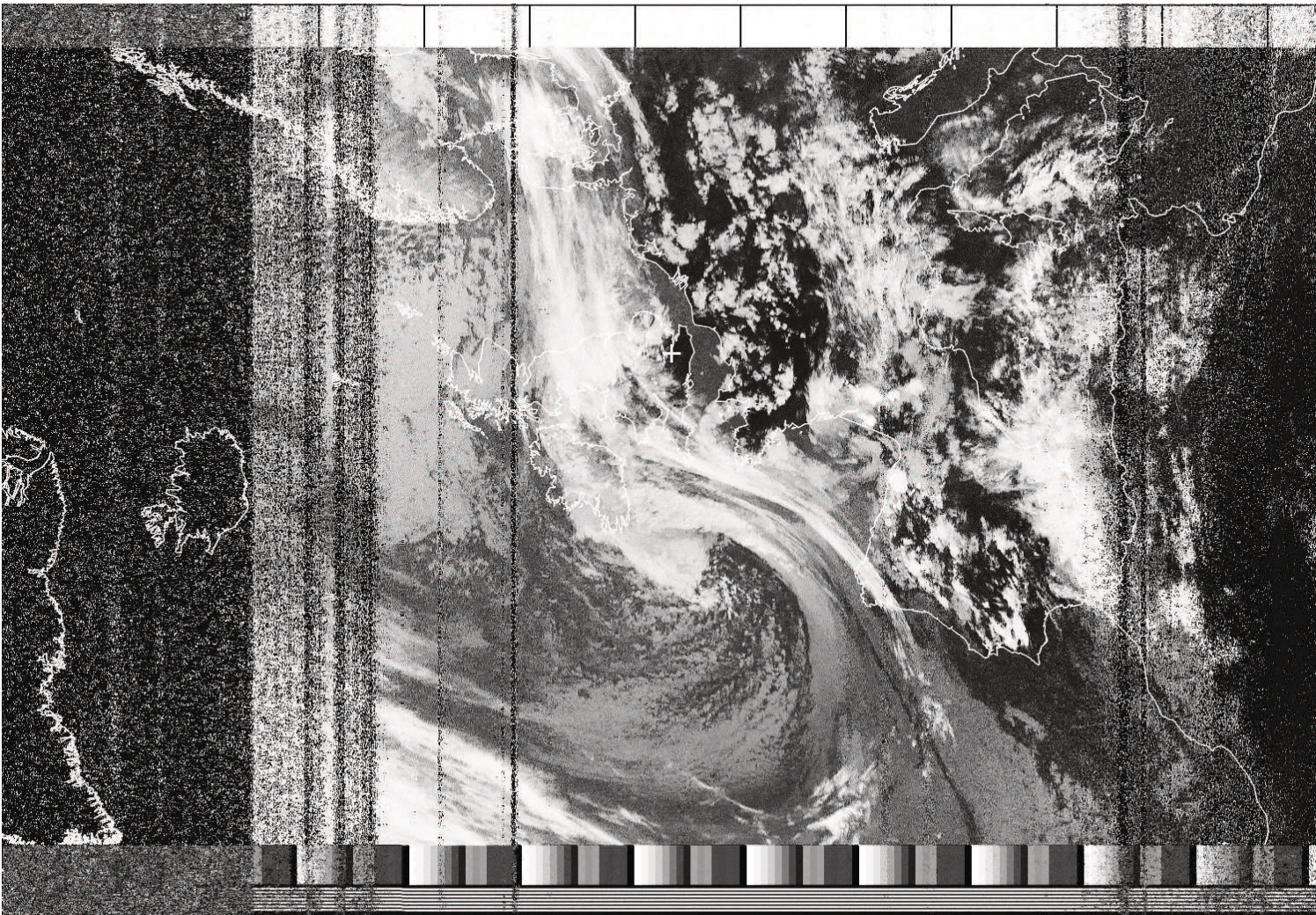


Image: OPEN WEATHER reading, Sasha Engelmann & Sophie Dyer, 2021

Open-weather is a feminist experiment in imaging and imagining the earth and its weather systems using DIY tools!

Co-led by researcher-designer Sophie Dyer and creative geographer Sasha Engelmann, open-weather encompasses a series of how-to guides, critical frameworks and public workshops on the reception of satellite images using free or inexpensive amateur radio technologies.

In the tradition of intersectional feminism, open-weather investigates the politics of location and interlocking oppressions that shape our capacities to observe, negotiate, and respond to the climate crisis.

In doing so, open-weather challenges dominant representations

of earth and environment while complicating ideas of the weather beyond the meteorological.

This workshop manual can be used as a tool by people who want to learn how to decode transmissions from National Oceanic and Atmospheric Administration (NOAA) satellites and to understand what's at stake when imaging the weather.

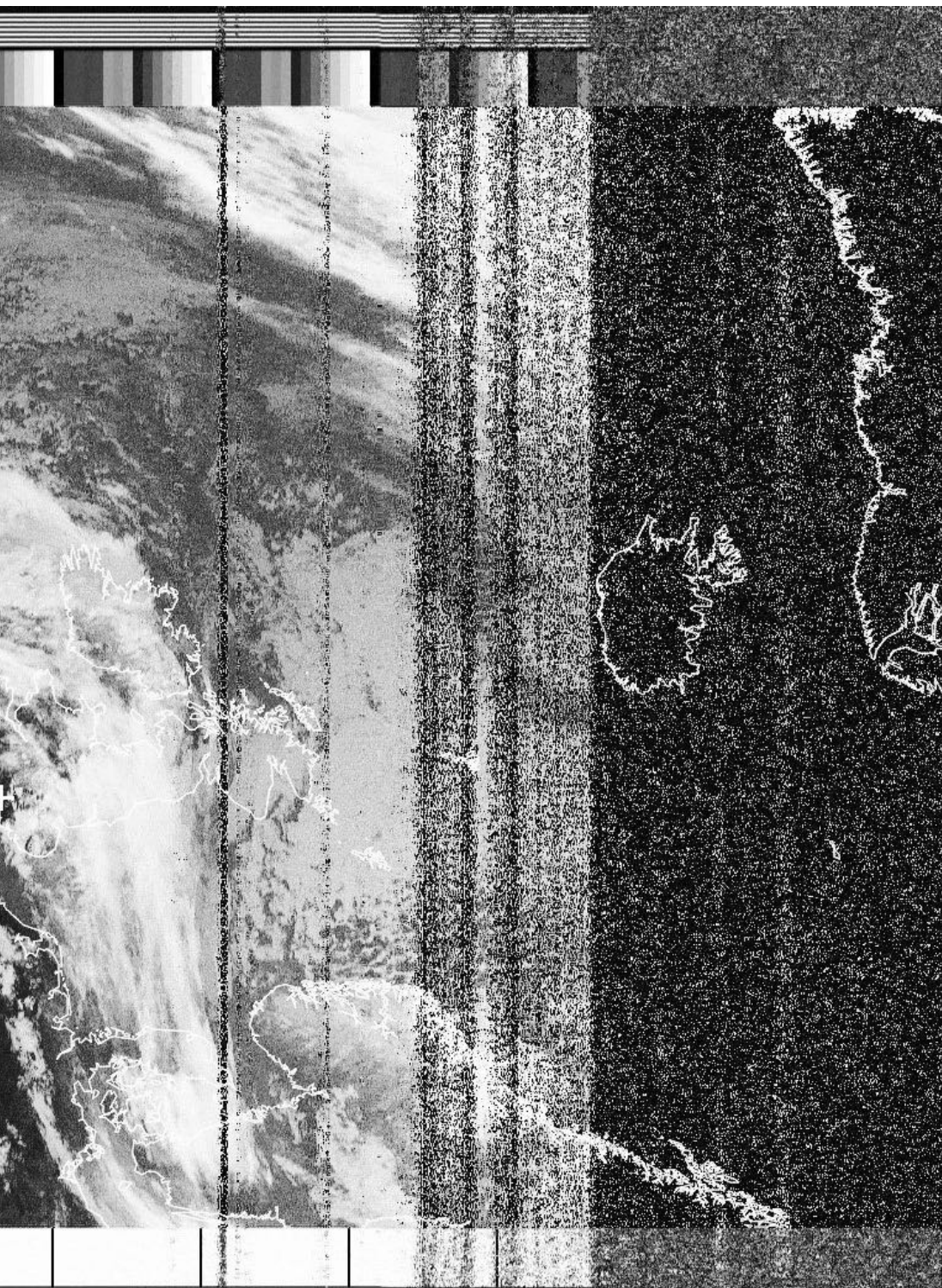
The workshop aims for inclusivity and access to amateur practices of satellite imagery reception and decoding and an alternative way of responding to the climate crisis.

Learn more about the project:

<https://open-weather.community/>

<https://cop26-nowcast.open-weather.community/>





# DIY satellite ground station workshop

by [open-weather](#)

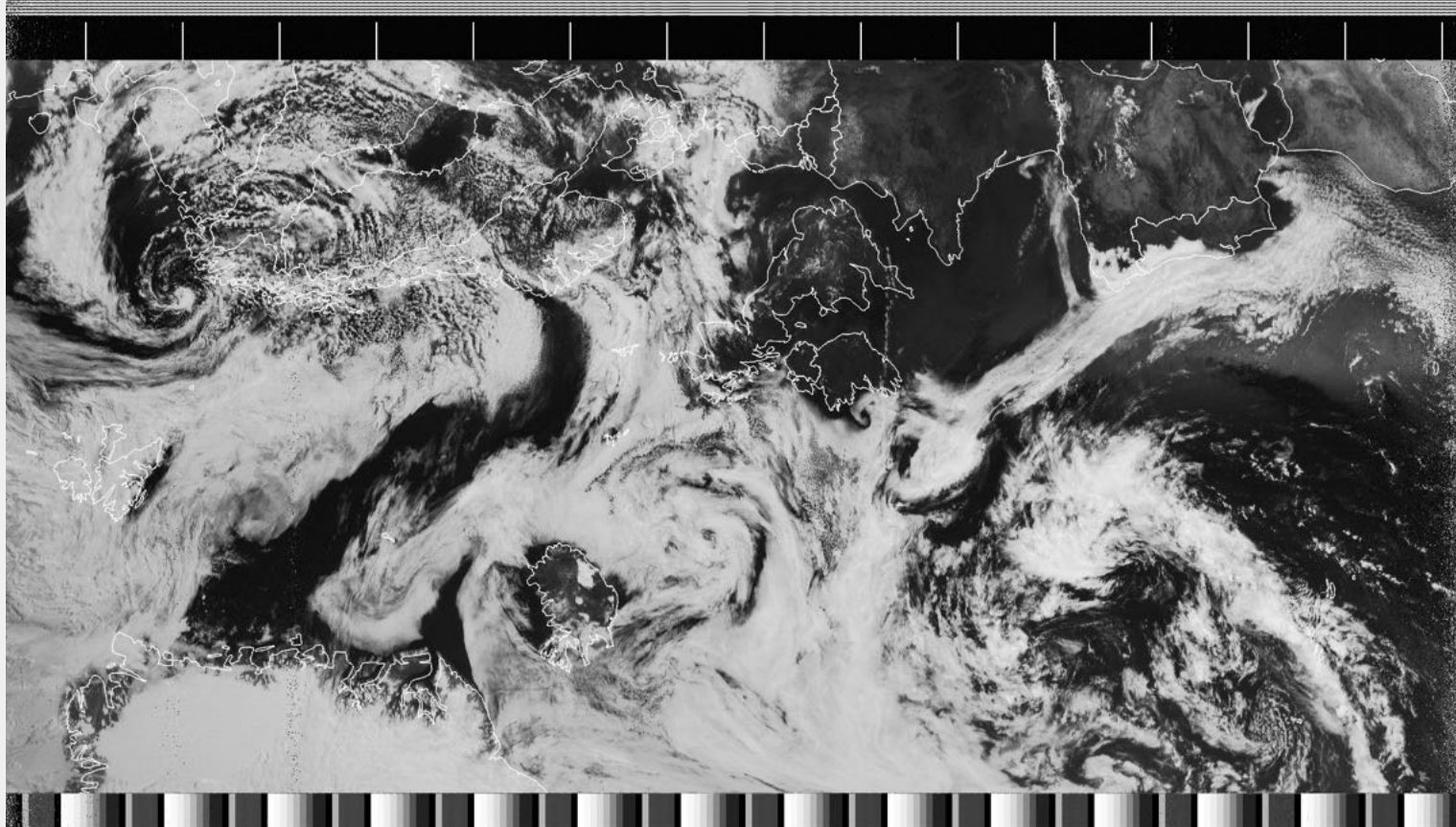
## Timetable

### Day 01

30 min	welcome
15 min	open-weather intro
1 hour	critical framing
20 min	break
1 hour	developing a shared understanding of radio
1 hour	long break
30 min	installing software
15 min	antenna assembly and set up
30 min	launching your DIY satellite ground station
30 min	set up for first satellite pass
30 min	satellite image decoding

### Day 02

1 hour	second satellite pass
15 min	break
30 min	how can I do this on my own?
1 hour	long break
1 hour	closing discussion



NOAA-19, 2021-07-20 12:18 GMT pristine from NOAA APT 1.3.0



# Day 01

## Welcome (30 min)

### Workshop protocols

- Inclusive language
- Be conscious of your contribution
- Anyone who does not want to be photographed, let us know

### Group intros

Sit in a circle and go round, sharing answers to the following question:

- Your name
- Your pronouns, if you want to
- How did you get to the workshop? (e.g. bike, walk, wander?)
- A reason why you signed-up?
- Your personal definition of “weather”

## Who and what is open-weather? (15 min)

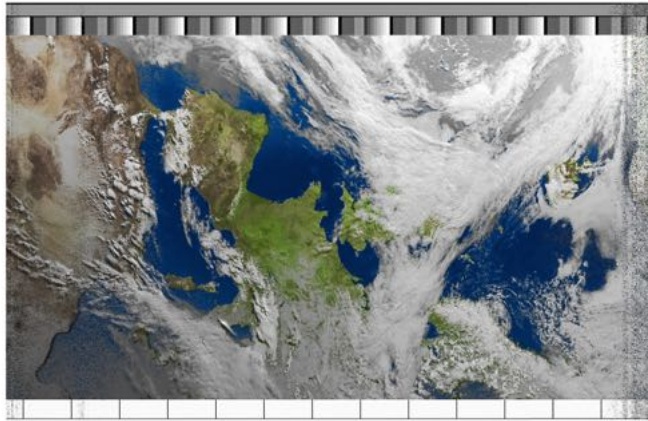
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<https://open-weather.community/>



NOAA 19 N 80 W 2020-05-17 18-03 BST Multi-spectral Analysis

## What you need

### Hardware

- A **computer** of any model. 4GB RAM or higher is ideal.
- A **software defined radio dongle**. There are many kinds are available:
  - [RTL-SDR V3](#) is the cheapest, reliable and most adaptable dongle, in our opinion. (£27)
  - [Airspy Mini](#) (£120)
  - [Funcube Dongle Pro+](#) \*Not compatible with CubicSDR (£150)
- An **antenna** capable of receiving circularly polarised transmissions:
  - [Turnstile](#) (£38)

We both use a turnstile antenna from AMSAT UK. AMSAT UK turnstile antennas come with the adapters and cables you need for satellite reception but no dongle---you need to purchase one separately.

  - [Quadrifilar Helix](#) (QFH)

### open-weather

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### satellite-imagery

7 following

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**Public Lab** is open for anyone and will always be free. By signing up you'll join a diverse group of community researchers and tap into a lot of grassroots expertise.

Sign up

## An Open-weather how-to guide on Public Lab

### About

- + [Goyang](#)  
at 22:35:08 UTC on 31 Oct. 2021
- + [Bangkhen, Bangkok](#)  
at 00:25:00 UTC on 31 Oct. 2021
- + [Bangkhen, Bangkok](#)  
at 02:42:51 UTC on 31 Oct. 2021
- + [Mumbai](#)  
at 02:04:44 UTC on 31 Oct. 2021
- + [Stuttgart](#)  
at 07:07:11 UTC on 31 Oct. 2021
- + [Mumbai](#)  
at 04:21:39 UTC on 31 Oct. 2021
- + [Schloss Solitude, Gerlingen](#)  
at 09:22:23 UTC on 31 Oct. 2021
- + [mar del plata](#)  
at 10:48:00 UTC on 31 Oct. 2021
- + [Mumbai](#)  
at 06:02:06 UTC on 31 Oct. 2021
- + [Venice](#)  
at 09:21:00 UTC on 31 Oct. 2021
- + [Reston, Virginia](#)  
at 12:10:59 UTC on 31 Oct. 2021
- + [Kirkenes](#)  
at 11:55:43 UTC on 31 Oct. 2021
- + [Paris](#)  
at 11:01:59 UTC on 31 Oct. 2021
- + [Santa Vittoria In Matenano](#)  
at 10:37:17 UTC on 30 Oct. 2021
- + [Jefferson Wisconsin](#)  
at 13:47:49 UTC on 31 Oct. 2021
- + [Jefferson Wisconsin](#)  
at 12:11:09 UTC on 31 Oct. 2021
- + [Glasgow, Scotland](#)  
at 11:01:12 UTC on 31 Oct. 2021
- + [Seattle, Washington](#)  
at 15:33:00 UTC on 31 Oct. 2021
- + [Norfolk, VA](#)  
at 20:12:30 UTC on 31 Oct. 2021
- + [Bucharest](#)  
at 16:55:46 UTC on 31 Oct. 2021

### When I image the earth, I imagine another

[Go to open-weather.community](#)



[Cop26-nowcast.open-weather.community](#). The Photographers' Gallery, 2021. Source: open-weather





*Isle of Mull, Scotland, 2020. Source: open-weather*

## Critical framing (1 hour)

### Radio amateurs or Ham radio operators

Together we will learn how to decode transmissions from National Oceanic and Atmospheric Administration (NOAA) satellites – this is part of a long history of radio-based practices, which have too often been limited to a small community of people called ‘radio amateurs’. Radio amateurs are citizens who are licensed to experiment with the radio spectrum.

### Cultural practitioners

There is, too, an artistic context to the work.

Several artists, including Afroditi Psarra, Audrey Briot, Xin Liu and Adriana Knouf, have also captured images from NOAA satellites, and have used these materials for installations, sculptures and performances.

#### **Question and mapping exercise**

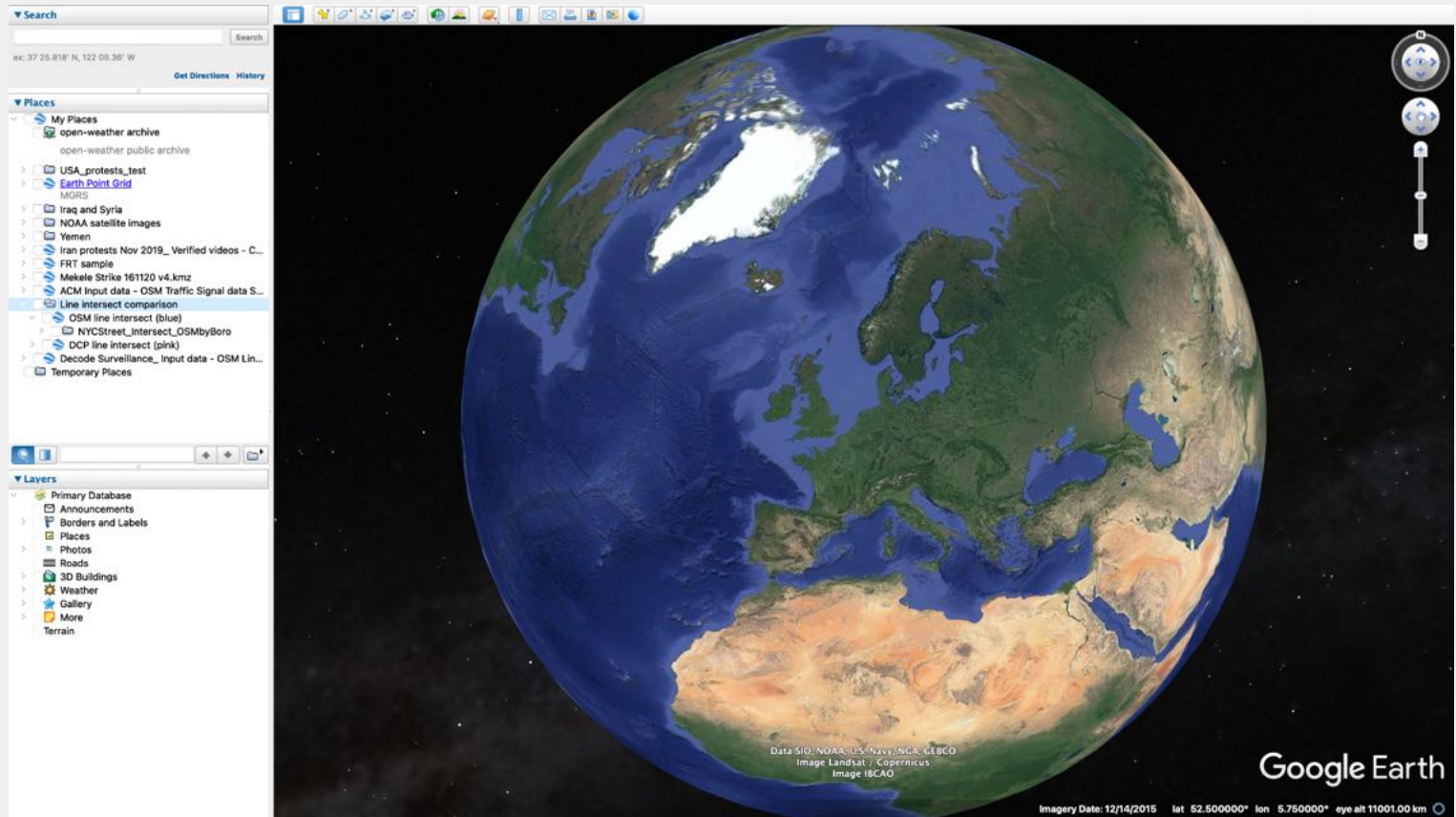
Who else is in this space?

What do you think is at stake when imaging the weather?

## What's at stake for open-weather?

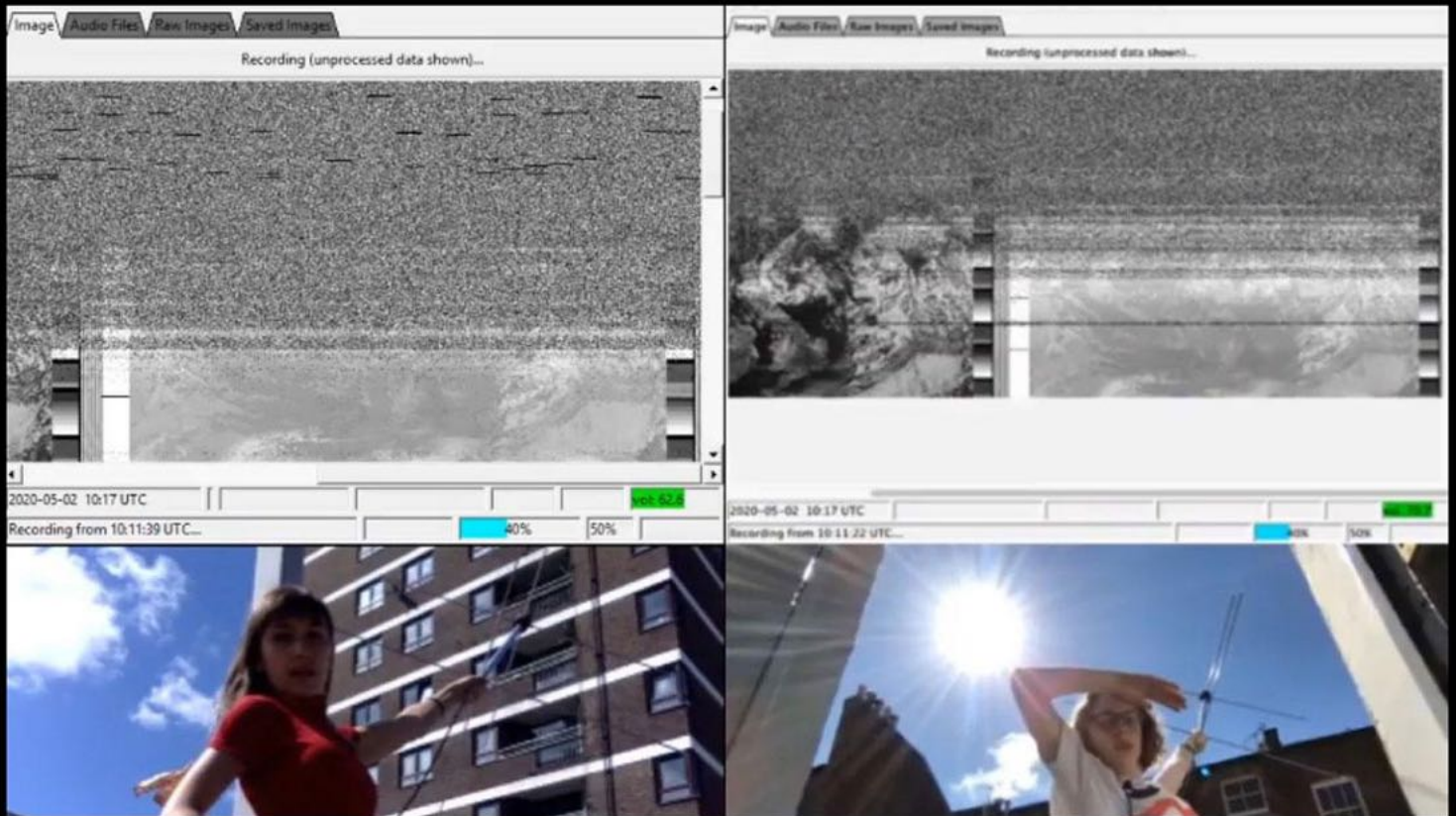
Open-weather is different from the above practices because of what we feel is at stake:

- How we image and imagine our world
- Inclusivity and access to amateur practices of satellite imagery reception and decoding
- An alternative way of responding to the climate crisis



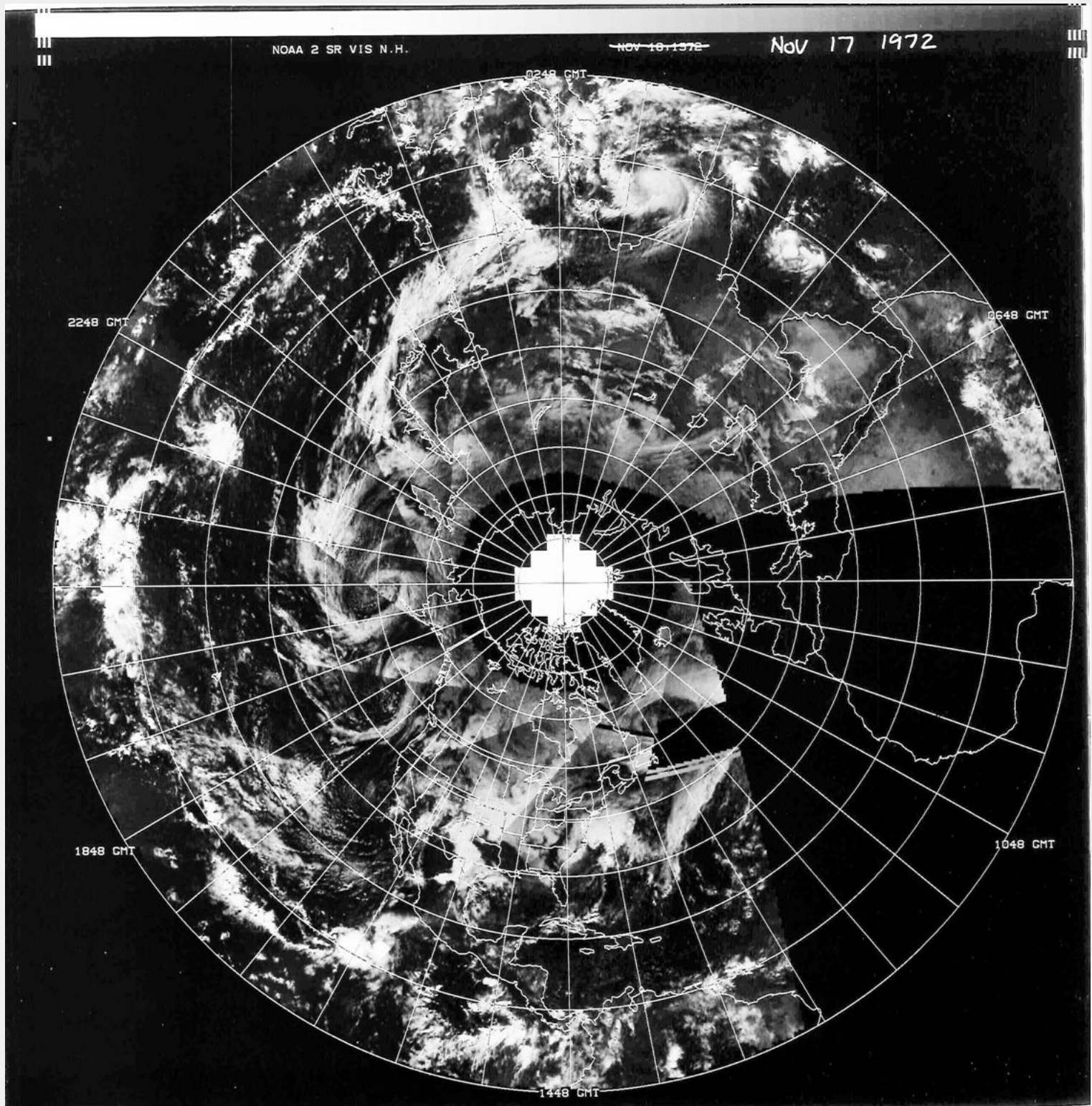
Google Earth Pro. Source: open-weather





*Open work, second body. Open-weather in collaboration with Daisy Hildyard. Soundcamp, 2020. Source: open-weather*

# We are interested in satellite imagery



*First images transmitted by NOAA-2 in 1972. Image courtesy of NOAA satellite data archives team.*

Since the 1960s our planet has been imaged by artificial, earth observation satellites.

A long line of feminist thinkers have critiqued satellite imagery  
e.g. "view from above" or "god's eye trick"

In open-weather, we are interested in appropriating, subverting and queering satellite imagery  
to ask: what would a feminist, people-powered image of the earth look like?



# Satellite imagery is transmitted via the radio spectrum

The radio spectrum is home to many different signals, information, noises made by individuals, institutions, machines, the earth, our sun, and other celestial bodies.

The radio spectrum is a congested space.

Satellite images are one of the many materials shared over the radio spectrum.

Library of waveforms: <https://www.sigidwiki.com/wiki/Database>

## Defining radio and key terms



Kenneth Fagg, Visualisation of radiation and radio waves produced for Life Magazine, 07 September 1960.



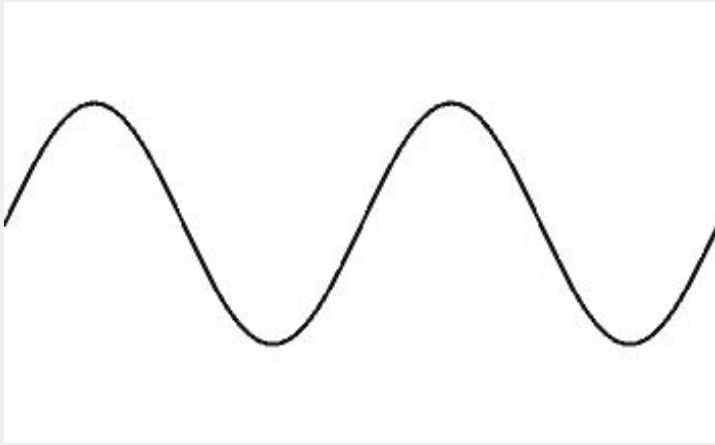
Here we are speaking from the standpoint of western science. Other cultures and traditions have their own ways of talking about and understanding radio. We are introducing a set of terms so that we have a shared language. Should you want to bring or develop an alternative set of terms please feel welcome.

What is radio?

- Radio is a **device** that traditionally contained a oscillator, modulator and amplifier.
- Radio is **electromagnetic waves** in the range of **300 Hz to 300 GHz** or wavelengths of **1,000 Km to 1 mm**

Radio waves are a form of **electromagnetic radiation**. Electromagnetic radiation is all around us, in many forms. Sunlight, X-rays and radioactivity are other types of electromagnetic radiation.

- Imagine a wave.
- The distance between two wave peaks is one 'cycle'. The number of cycles per second is measured in Hertz (Hz).
- This is the **frequency**.
- The frequency of radio waves is between 300 kHz and 300 GHz.



Wave oscillation diagram. Source: bestanimations.com

- **Wavelength** refers to the distance between two of the peaks in a wave.
- Wavelength has a direct relationship to frequency. The longer the wavelength the lower the frequency.
- For example, NOAA satellites transmit radio waves at **137 MHz (137,000,000 Hz)** and their wavelength is 2.18m.

When we talk about radio waves we always specify the frequency or wavelength, since this determines some key properties of the wave e.g. how far it can travel and what antenna you need to tune to it.

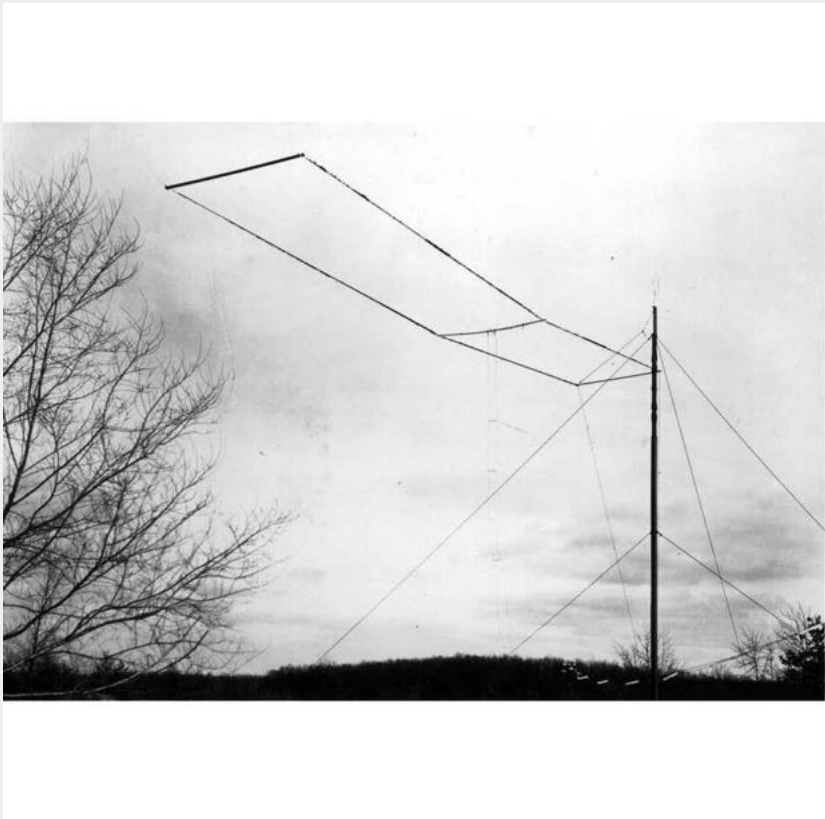
An **antenna** is a device that can transmit and receive radio waves.

In today's workshop, our antennas will be receiving radio waves transmitted by antennas on NOAA satellites. We will be receiving radio waves that originate from the antenna of the NOAA satellite, pass through earth's atmosphere, and arrive at earth's surface.





Aouefa Ammoussovi with her V-Dipole radio antenna during a DIY Satellite Ground Station Workshop; Stuttgart, 2020.  
Source: open-weather



Antenna designs. Source: unknown.



# Access to the radio spectrum

The radio spectrum is a noisy space.

Access to frequencies that are useful for telecommunication is negotiated.

Multiple transmissions on similar frequencies can interfere with each other.

Countries and regions have established agreements for the organisation of the radio spectrum. Often, frequencies are auctioned to the highest bidder. Governments, militaries and scientific institutions all make use of specific frequencies.

This is political.

Who governs the radio spectrum and how?

Who or what gets access?

Who is excluded?

What values, modes of governance, ways of being in the world are reproduced?

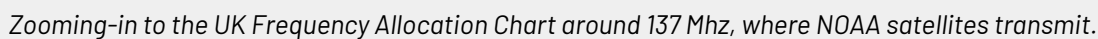


World Radiocommunication Conference 2015. Geneva, Switzerland. Source: International Telecommunication Union



### Short Range Devices (SRDs) Shared Allocations Acronyms

A - Alerts	MDA - Movement Detection or Alert
AA - Automatic Audio	MS - Non-Specific Identification, Confidentiality and Telecommunication
D - Database	RFID - Radio Frequency ID
DGV - Detection of Avionics Victims	RM - Radio Microphones
GP - General Purpose SRDs	RTT - Road Transport and Traffic Telematics
HA - Hearing Aids	TTT - Telemetry and Telecommunication Commercial
IA - Interference Applications	TTT - Telemetry and Telecommunication General
IC - Infrared Data Link	UHF - Ultra High Frequency
LAN - Local Area Network	VD - Video Distribution
LM - Medical and Biological	ULPM - Ultra Low Power Active Medical Implants
MC - Model Censor	WA - Wireless Audio
MS - Metal Detectors	WVC - Wireless Video Cameras





Wi-Fi access point weatherised with flowerpot in Calais, France, 2015. Source: [Jangala](#)



## BRURSHANDEL SNELHEIDSRACE

# Brits gehucht krijgt zijn eigen Eiffeltoren – voor de flitshandel

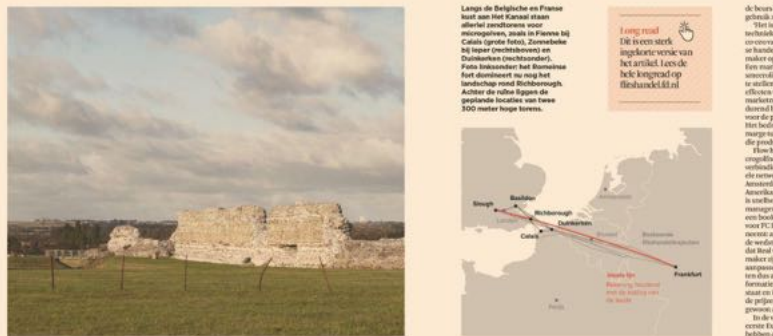
Beursbedrijven zitten midden in een race. Wie het snelst data tussen Frankfurt en Londen verstuurt wint. Een netwerk van radiotoren tussen de twee financiële centra moet microsecondes tijdswinst opleveren

Door Joost Dobber  
Fotografie: Eline Benjaminsen

**H**ier het andere netwerk heeft, aan het momenteel. Daarom zijn er nu twee bedrijven die hier ieder een toren van meer dan 300 meter hoog willen bouwen, zodat ze euhel microsecondes tijdswinst kunnen behalen.

Een microseconde is een tiende van een seconde. Het verschil lijkt niet erg groot, maar het is wel een verschil. Wie het snelst data tussen Frankfurt en Londen verstuurt wint. Een netwerk van radiotoren tussen de twee financiële centra moet microsecondes tijdswinst opleveren.

De toren van de ene kant is nu al op de plaats. De toren van de andere kant is nu al op de plaats. De toren van de ene kant is nu al op de plaats. De toren van de andere kant is nu al op de plaats.



'British hamlet gets its own Eiffel Tower - for high-frequency trading' (Brits gehucht krijgt zijn eigen Eiffeltoren - voor de flitshandel)

Source: Eline Benjaminsen

## Our political position is a feminist one!

For us, feminism is intersectional. It is a project informed not only by gender and sexuality, but also by race, class, location, ability, power and privilege.

As Lola Olufemi puts it, that 'Feminist work is justice work' (2020: 5).

Feminism has a purpose beyond highlighting the ways women are discriminated against.

Instead feminism is about remedying the 'consequences of gendered oppression through organising and by proposing new ways to think about our potential as human beings' (Olufemi, 2020: 6). To do 'justice work' is to remagine the world, toward a liberated future for all.

'Feminism is a political project about what could be' (Olufemi, 2020: 1)

## The open-weather feminist principles

### Situated knowledge

- we counter the smooth, seamless globe
- we locate ourselves in specific place (geographic space, time, language, culture, gender, sex, race, ability, class, ...)
- we recognise that our view is always partial

### Our bodies count

- we centre the body as a technology that is entangled with radio antennas, cables and software
- our bodies are written into satellite imagery
- and coded in different ways

### Power

- we recognise the histories and origins of the remote sensing technologies that we use
- the vast power inequalities that are the intrinsic to remote sensing e.g. who is sensing and who is being sensed
- studying these power relations helps us deconstruct and subvert them

### Access

- radio amateurism too often excludes anyone who is not 'pale, male, and stale'
- guides are often written presuming prior knowledge, financial resources and leisure
- limiting who has access to radio amateur technology and knowledge, limits how it is used, for what purpose and to what ends.

These feminist propositions become tools and ways of working.

They inform everything we do, e.g.

- How we collaborate, make decisions, and organise
- Which spaces we choose to work in
- How we theorise and conceptualise
- What we value and prioritise

A full list of our feminist principles is found in the [open-weather feminist handbook](#).

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OPEN-WEATHER FEMINIST  
HANDBOOK  
03 December 2020  
Online

Who or what gains power from satellite imagery, radio technology and meteorological data?

Sophie Dyer and Sasha Engelmann join us as part of *#almanaccare* by sharing for the first time the series of feminist principles guiding their *open-weather project*, which probes the noisy relationships between bodies, atmospheres and weather systems.

The open-weather feminist handbook has been informed by over two years of open-weather experiments in satellite image decoding, amateur radio, open data, and feminist tactics of sensing and séance. It is a living document co-written by Sasha Engelmann and Sophie Dyer. Inspiration for this document comes from many places, but it is informed greatly by the *CLEAR Lab Handbook*.

Foregrounding the body as a situated technology, as much as a method and analytic, the open-weather feminist handbook seeks to be a shared resource to map and challenge structures and narratives of domination involving weather data collection and access, while complicating ideas of the weather beyond the meteorological.

The event has been organised by Bianca Stoppioni.

Sophie Dyer is a feminist researcher, designer, and activist, specialised in visual and open source investigations. She works with Amnesty International's Evidence Lab and is an Affiliate of The Berkman Klein Center for Internet & Society at Harvard University.

Sasha Engelmann explores interdisciplinary, feminist and creative approaches to environmental sensing. She is Lecturer in GeoHumanities at Royal Holloway University of London and a fellow at Akademie Schloss Solitude, Stuttgart.

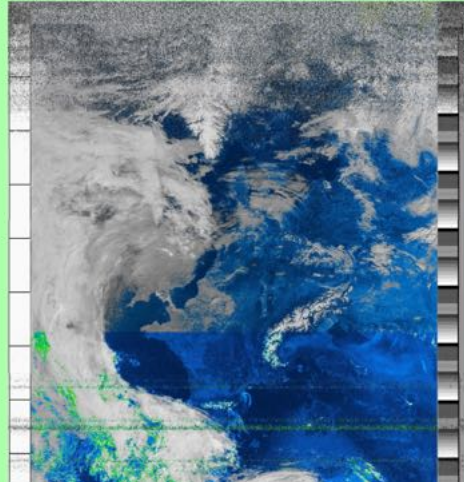
The project is supported by Arts Council England Grants for the Arts.

Supported using public funding by  
**ARTS COUNCIL  
ENGLAND**

# open-weather handbook

The open-weather handbook is a shared resource and series of values and positions that emerged over two years during which the open-weather project took shape. It is a *living document* co-written by Sasha Engelmann and Sophie Dyer. Inspiration for this document comes from many places, but it is informed greatly by the [CLEAR Lab Handbook](#).

It was last updated on 22 Dec. 2020 in Stuttgart, Germany and London, UK.



Open-weather protocols written down. Almanac, 2020.

Source: <https://almanacprojects.com/public-programme/open-weather-feminist-handbook>

In summary, as open-weather, we ask:

What would it mean to engage with the radio spectrum and satellite imagery in a feminist mode?

Suggested break (20 min)

Developing a shared understanding of radio (1 hour)

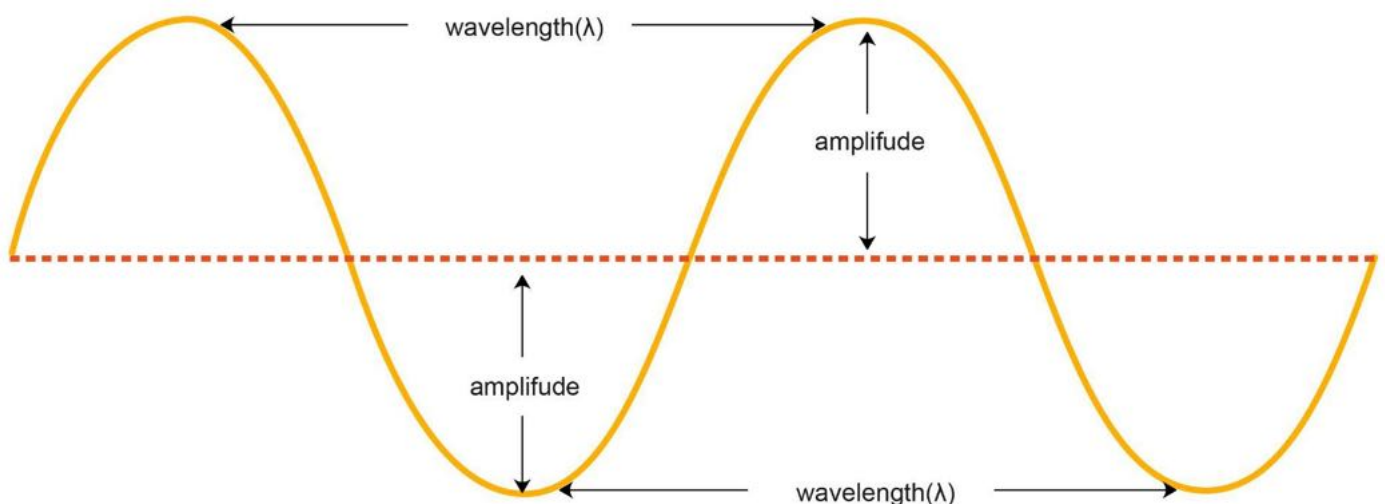


Diagram of a transverse wave showing the wavelength and amplitude. Source: Unknown



## Modulation FM, AM, there are other common modes

Radio waves can carry information e.g. audio

'Modulation' refers to the way in which information, including audio, is stored or "encoded" into a radio wave.

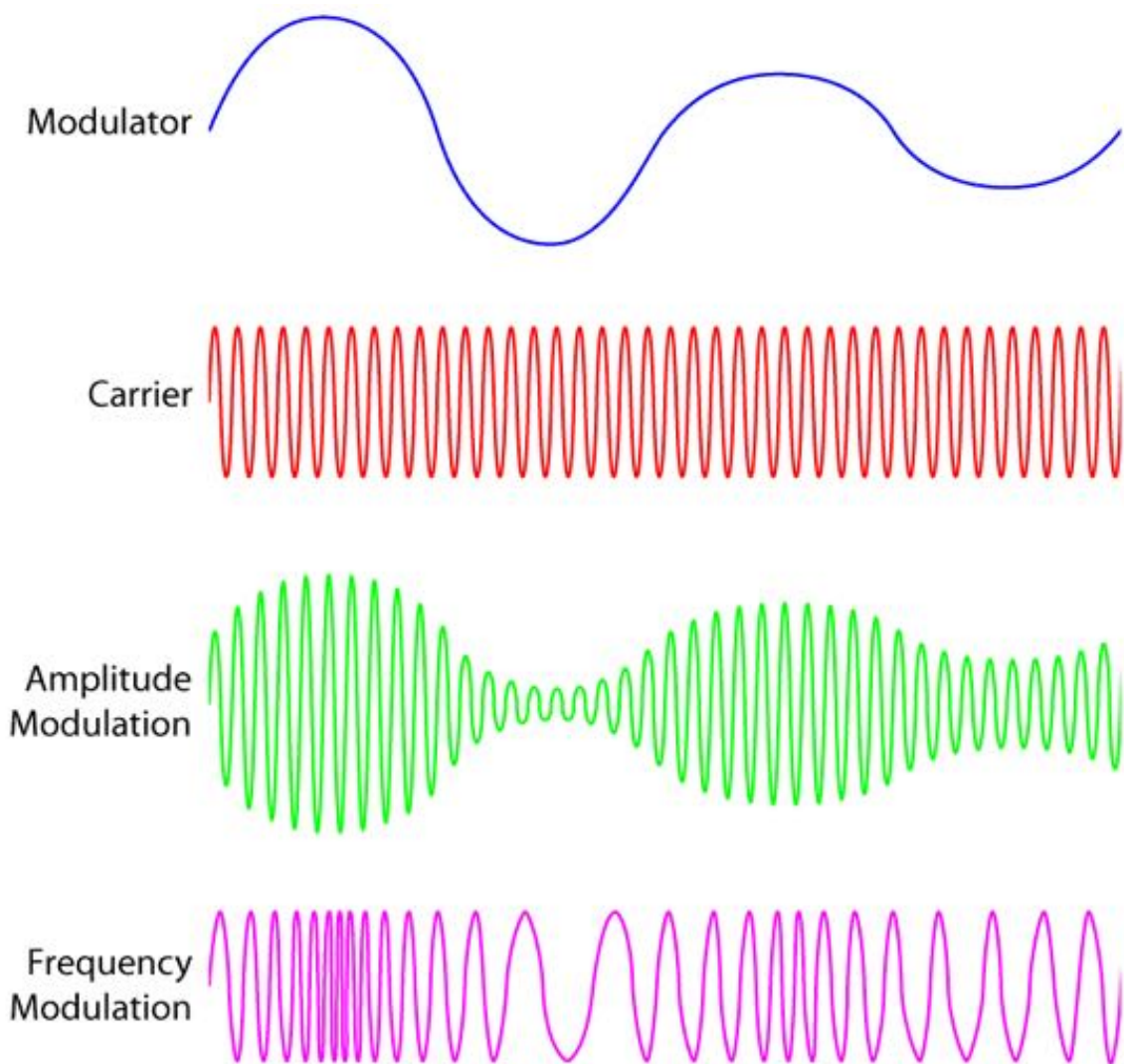
Common types of modulation include FM, AM, USB, LSB and CW (morse!)

### Frequency modulation

The FM in "FM radio" refers to a type of modulation called frequency modulation. In FM the information is contained in the frequency of the wave.

### Amplitude modulation

The AM in "AM radio" refers to the type of modulation called amplitude modulation. In AM the information is encoded in the amplitude of the wave.



Transmissions from NOAA satellites are **FM**

meaning the transmitter on the satellite oscillates a carrier wave at the same frequency as an audio signal.

## Transmission and propagation

### Transmission: How radio waves are passed from one place to another

Many things can transmit radio waves e.g. the sun

In this workshop we are interested in radio waves transmitted by antennas.

Antennas can transmit and receive radio waves

Radio waves travel through space and the atmosphere at the speed of light.

### Propagation: How radio travels

The way radio waves behave when they travel is called propagation.

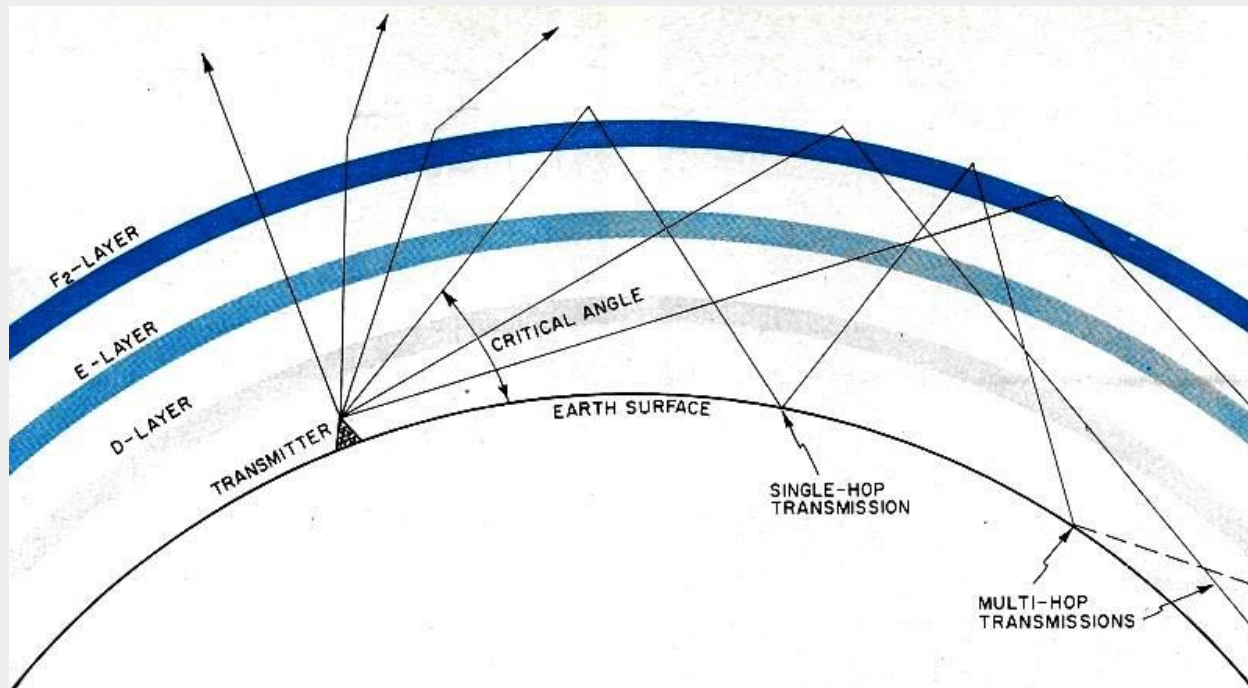
How radio waves propagate depends on the frequency.

#### Line-of-sight propagation

- Radio waves travelling a straight line from antenna to antenna
- As the name suggests, this is limited to the line-of-sight, and so depends on how high your transmitting and receiving antennas are positioned.
- Line-of-sight is used for medium range radio transmission including mobile phones, wireless networks, FM radio, TV and **NOAA satellites**.

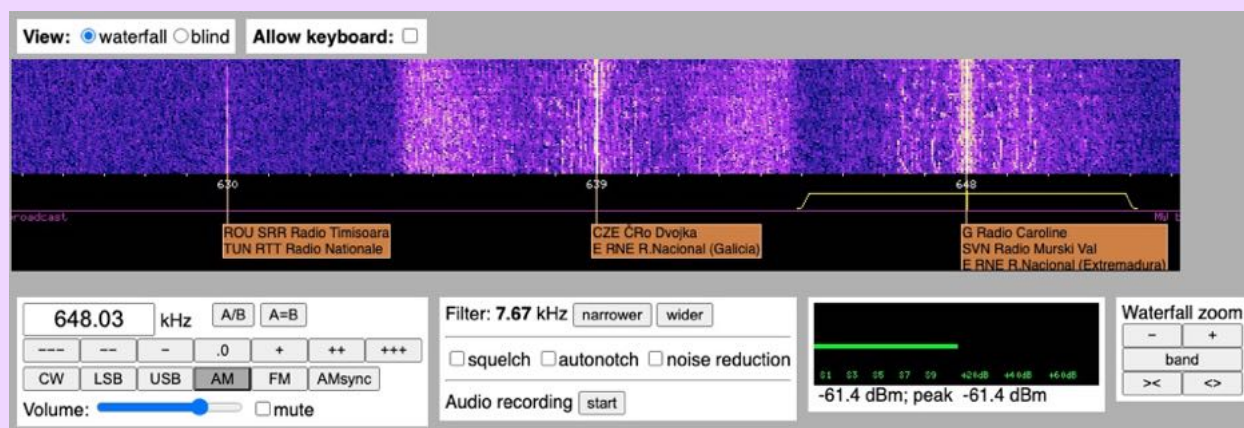
#### Skywave propagation

- Radio waves that travel beyond the horizon by being bounced (refracted) off the earth's ionosphere – a layer of ionised particles between 70 and 400 km above the earth's surface.
- Skywave propagation is influenced by the time of day, seasons, weather, and the sunspot cycles, and so can be both unexpectedly useful and unreliable.



Skywave Propagation. Source: [RF Cafe](https://www.rfcafe.com)

## Tuning exercises: WebSDR



A screenshot of the WebSDR interface that can be used to listen to the radio spectrum online.

WebSDR allows users to tune to software defined radios around the world.

In the following exercises, we will listen to the radio spectrum using [WebSDR](https://websdr.ewi.utwente.nl) and a mini-loop antenna at the University of Twente, Netherlands. The following exercises will get you familiar with changing frequencies, modes and using a waterfall display, much like the CubicSDR software we will use later to receive NOAA satellites.

### Exercise 1: Radio Caroline<sup>1</sup>

In your browser, open: <http://websdr.ewi.utwente.nl:8901/>

In the Frequency Box (left under the waterfall) type in **648**.

<sup>1</sup> This exercise is inspired by Hannah Kemp-Welch's 'Shortwave Listening Toolkit', developed for workshops and community dialogues through a commission for the global sound arts festival Reveil 2020 with Soundcamp.



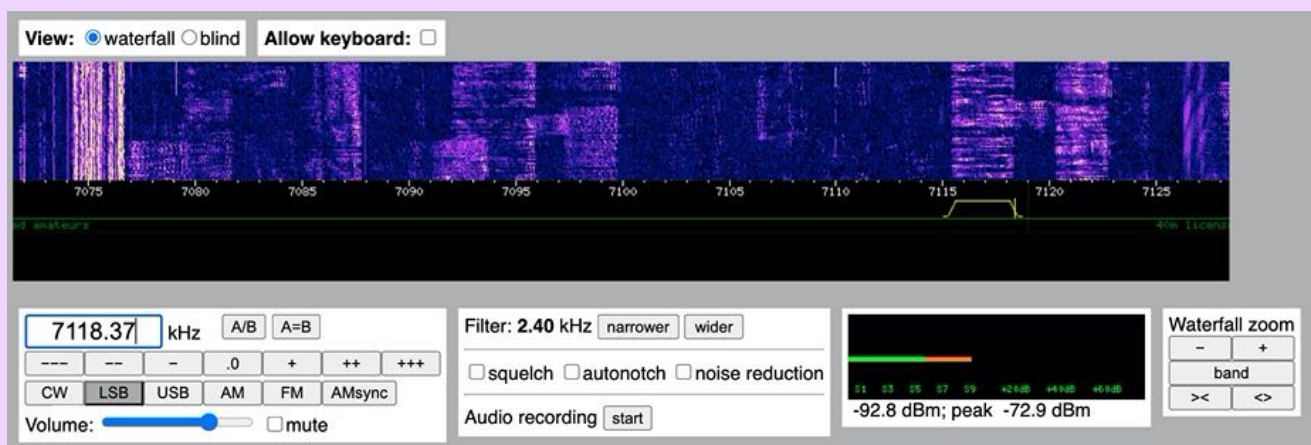
In the 'Waterfall Zoom' box (below and right of the waterfall) use the + sign to **zoom in** until you can see the orange labels.

**Click and drag** the waterfall display so that the signal you are receiving is in the middle of your screen.

For Mode (CW, LSB, USB, AM, FM, etc) select **AM**.

Make sure the yellow signal selector (which looks like a thin yellow bracket under the waterfall display) is covering the whole signal. Adjust the width of the yellow selector by clicking one of its 'feet' and pulling it left or right. What can you hear? Anything?

After some listening, **click directly on the number 639** under the waterfall display to listen to Czech Radio Dvojka (only sometimes audible due to variable skywave propagation). What other radio stations can you listen to by dragging the waterfall and clicking on different frequencies?



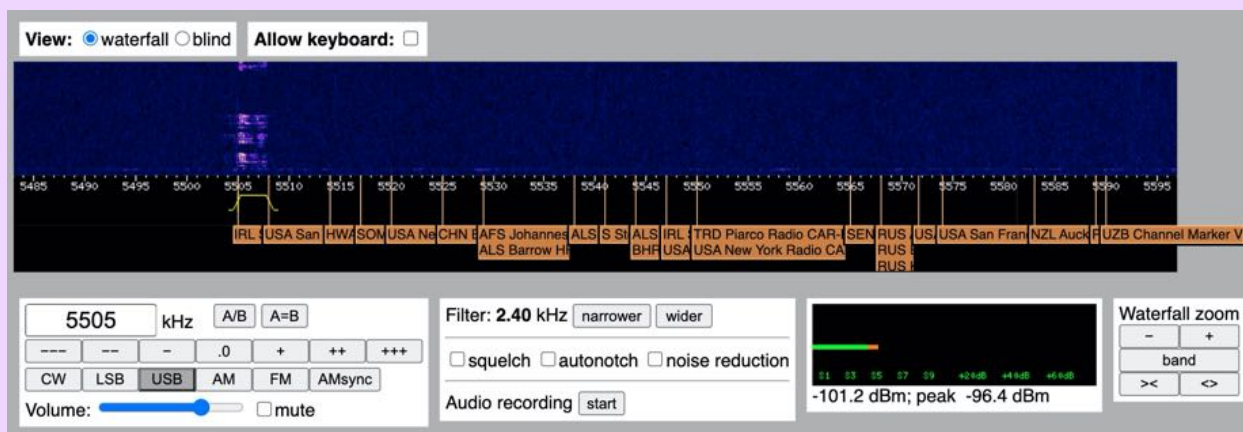
## Exercise 2: Amateur Radio

In the Frequency Box, type in **7100**.

**Zoom in or out** as needed.

For Mode, choose **LSB**.

Click around in the waterfall display to find a strong signal near / next to 7100 KHz. If possible, determine what language is being spoken and (bonus!) what is being said.



### Exercise 3: Weather Report for Transatlantic Aircraft

(Note: This frequency can be silent – see if you get lucky!)

In the Frequency Box, type in **5505**.

For Mode, choose **USB**.

Be sure the yellow cursor is centred on the transmission and capturing the full width of the signal. What can you hear?

These are only some of the signals we can listen to by using WebSDR. Since radio propagation changes with the quality of the ionosphere in the atmosphere, returning to WebSDR at different times of the day will reveal different signals from different parts of the world.

## Satellites orbits and radio

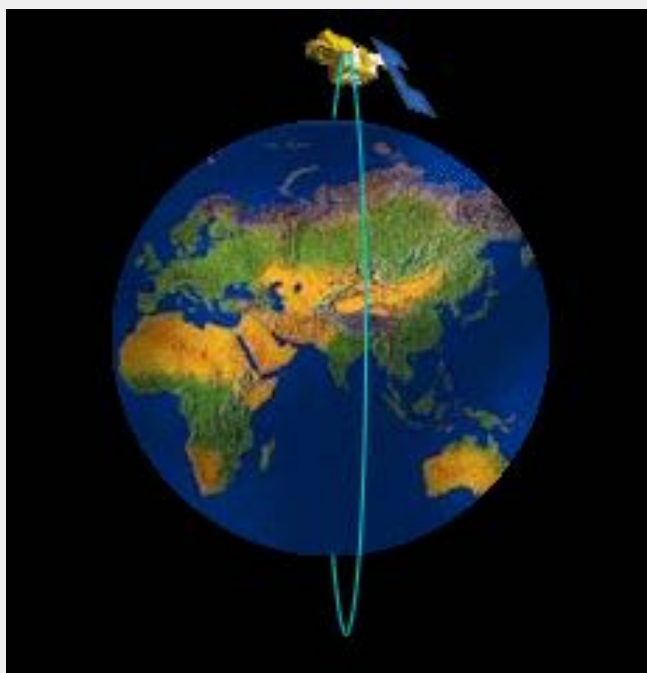
The earth is surrounded by satellites. These satellites each use different radio frequencies to send information back to earth's surface. Many different forms of modulation are employed, and many satellite transmissions are encrypted. NOAA satellites rely on radio waves to transmit meteorological and environmental data to earth's surface, and NOAA signals encode data that can be demodulated by the public.



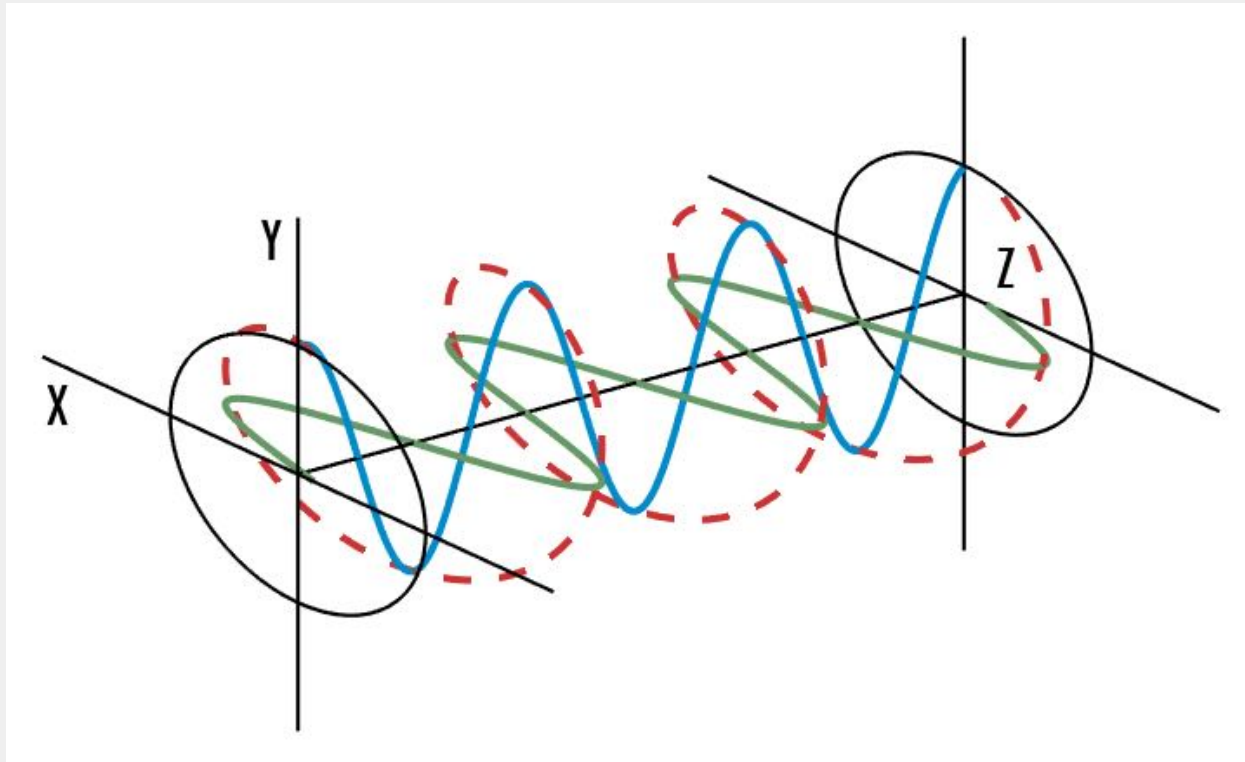


The current space-based portion of the World Meteorological Organization's Global Observing System, plus additional space weather and environmental satellites. Source: [NOAA](https://www.noaa.gov)

NOAA satellites orbit around the poles of the earth in order to maximise the amount of meteorological information collected and transmitted. It takes about 100 minutes for a NOAA satellite to make a full orbit. As the earth spins underneath, the satellite passes over different continents, oceans and places.



NOAA 15, NOAA 18 and NOAA 19 satellites follow a polar orbit. Each orbit takes approximately 102.1 minutes.



What do NOAA satellites transmit? Right-hand circularly polarised electromagnetic waves.

Though it is beyond the scope of today’s introductory workshop, the FM modulated transmissions of NOAA satellites are [right-handed circularly polarised](#). This means that we need antennas that are able to capture circularly polarised signals (V-dipoles, Turnstiles or QFH antennas).

### How do NOAA satellites collect data?

The images transmitted by NOAA satellites are produced by the satellite's primary scanning instrument called the Advanced Very High Resolution Radiometer (AVHRR). The instrument is designed to detect six channels of radiant energy from the surface of the Earth ranging from the visible spectrum to infrared or thermal spectra.

As the satellite passes over a given part of the earth, the AVHRR sensors collect and transmit data in near-real time. Think of the satellite as scanning Earth's surface line by line. In the resulting images each pixel covers an area approximately  $4 \times 4$  km.

### How do they transmit data?

The NOAA satellites have radio antennas that transmit the data back to Earth on a frequency in the 137 MHz range. To minimise interference between satellites, each NOAA satellite transmits on a different frequency within the 137 MHz range.

Satellite	APT transmission frequency in <b>Hertz or Hz</b>	APT transmission frequency in <b>MegaHertz or MHz</b> (most common format)
NOAA 19	137100000	137.1



NOAA 18	137912500	137.9125
NOAA 15	137620000	137.62

**How do NOAA satellites orbit?**

NOAA satellites orbit the Earth in a sun-synchronous orbit. A sun-synchronous orbit is a nearly polar orbit in which the satellite passes over a given point of the planet's surface at approximately the same time everyday.

The NOAA satellites follow a Low Earth Orbit (LEO) at around 800–1000 km.

Each NOAA satellite circles the Earth approximately every 100 minutes.

**How long will the NOAA fleet be alive?**

They may be turned off at any moment! This means there is a necessity to work with these satellites before they stop transmitting.

Suggested long break (1 hour)

Software for radio reception (30 min)

**Software-defined radio a.k.a. SDR**

SDR is a virtual radio.

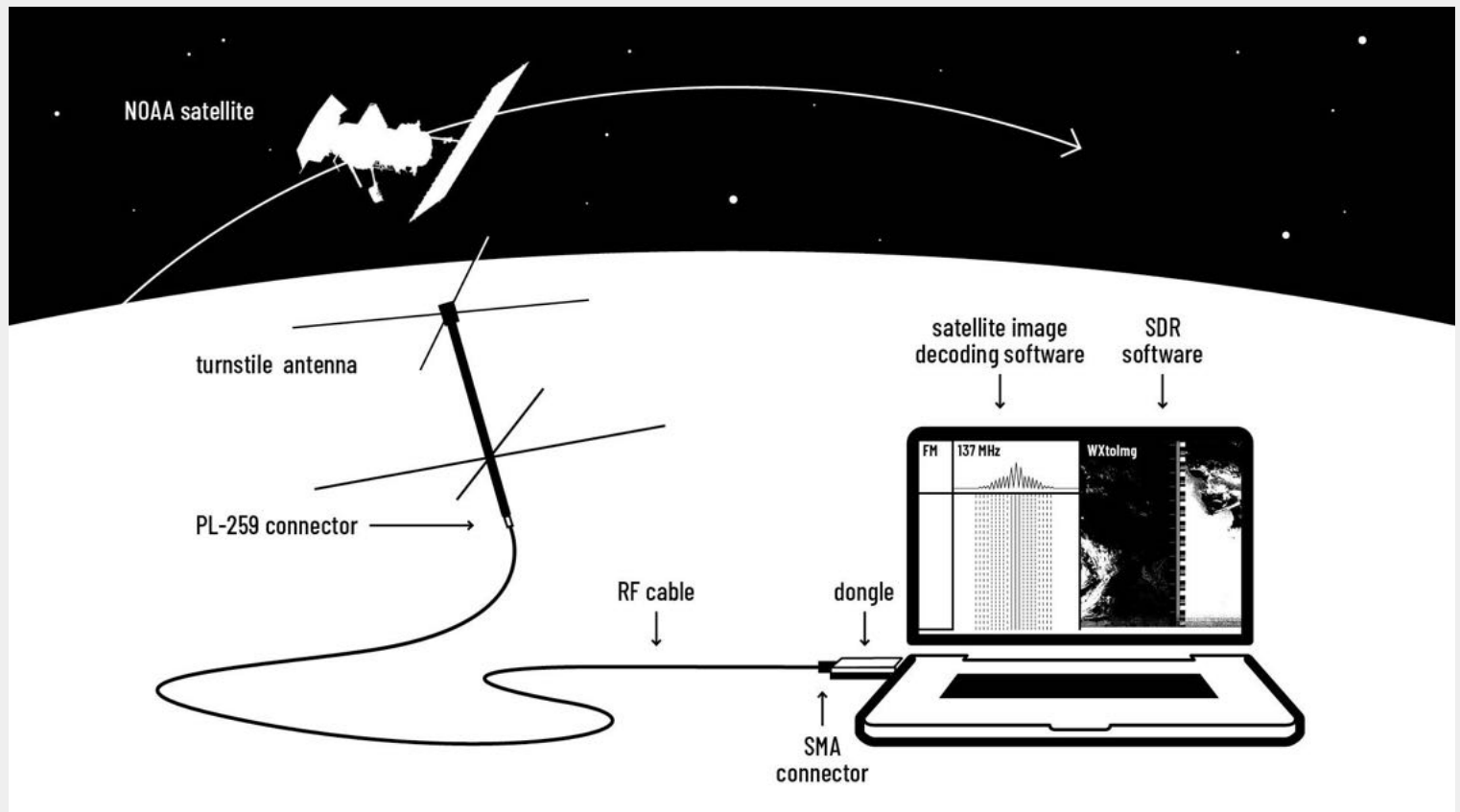


*Radio shack. Source: DD1US*



*n.n.n. collective decoding a satellite pass in Stuttgart, January 2021.*

## How and SDR is part of a DIY satellite ground station



*A DIY Satellite Ground Station, including hardware and software. Open-weather CC BY 4.0*

This diagram shows how an antenna connects to a radio frequency cable, then to a dongle, and to a laptop. Depending on what kind of antenna and set of cables you have, you may have a longer USB cable that connects your dongle to your laptop. Do note that newer Macs will require a USB-C to USB-A adapter so that the dongle can plug in to the computer's USB ports.

### **Installing a software defined radio and a sound editing programme, if needed**

Everyone should install CubicSDR and Audacity, if you don't have it already.

CubicSDR is a software defined radio programme that allows you to tune to frequencies in the electromagnetic spectrum, including the frequencies used by NOAA satellites.

Windows users also need a software called Zadig.

For the following operating systems, download and install:



## Mac OS

- [CubicSDR](#) for Mac
- [Audacity](#) for Mac

## Windows

- [CubicSDR](#) for Windows\*
- [Zadig](#)\*
- [Audacity](#) for Windows

\*Save the file on your device somewhere that is not 'Program Files' e.g. your desktop

## Linux

- [CubicSDR](#) for Linux or get the [Skywave Linux](#) package
- [Audacity](#) for Linux

# Antenna assembly and set-Up (15 min)

Example antenna types suitable for receiving NOAA satellites:

- **V-Dipole antennas** are versatile and inexpensive. When set up, they look like a V
- **Turnstile** antenna looks like two metal crosses along a metal pole.
- **Quadrifilar Helix** antenna looks like a spiral of DNA

If you are using **v-dipole** antennas in the workshop:

- Assemble the antenna kit
- Extend the metal dipoles to 54.5 cm  
(54.5 cm is a quarter of the wavelength of 137.5MHz)
- Open the dipoles 120 degrees apart
- Use the mini tripod to angle the v-dipole so that it is parallel to the ground
- Orientate the antenna so that it is on a North-South axis



*Left: top view of V-Dipole. South is to the top. Right: side view of V-Dipole. South is to the right.*

If you are using **turnstile** antennas in the workshop:

Build up your antenna by screwing the short metal pieces into the 'top' of the antenna pole, and the longer ones toward the bottom. When the satellite pass is due to begin, you will start by pointing the antenna at the horizon that the satellite is due to crest. (Hint: If a satellite pass is 'Northbound' start by pointing your antenna South; if a pass is 'Southbound' point your antenna North).

You will need to track the satellite as it orbits overhead during the pass. This means you need to know the satellite's maximum elevation, and how long the pass will last. At the end of the pass your antenna should be pointing at the opposite horizon.



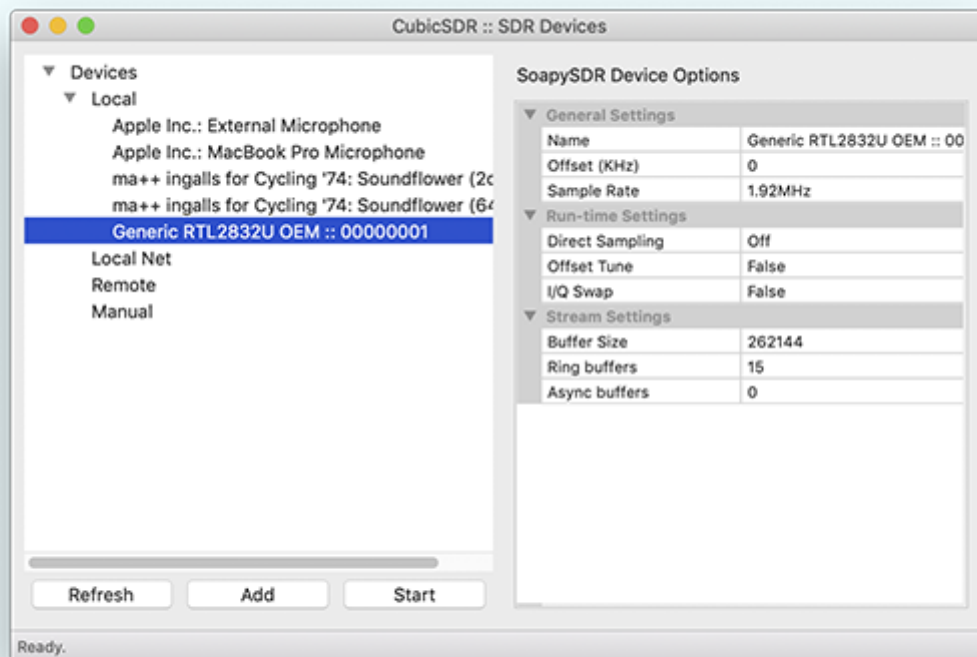
*M6NYX uses a turnstile antenna for a NOAA pass that is almost 90 degrees at its maximum elevation. Source: open-weather*

## Launching your DIY satellite ground station (30 min)

### Mac OS

1. Build up antennas and link cables and dongles to computers.
2. Make sure your dongle is plugged securely into a USB port on your laptop. Launch CubicSDR
3. In the dialog window select your dongle from the Devices list and click Start. For the RTL-SDR dongle select "Generic RTL2832U OEM :: 00000001".

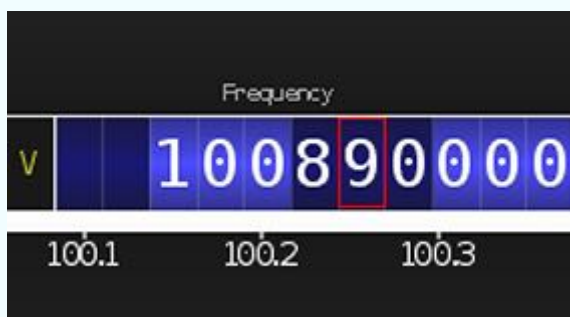




4. To check CubicSDR is working, click anywhere on the top waterfall window. You will hear static / radio noises and see the waterfall moving.

5. Tune to a frequency. There are several easy ways to tune to a frequency in CubicSDR

Under the label 'Frequency', click on the upper and lower halves of the numbers. This will change the numbers and thus the frequency you are listening to.

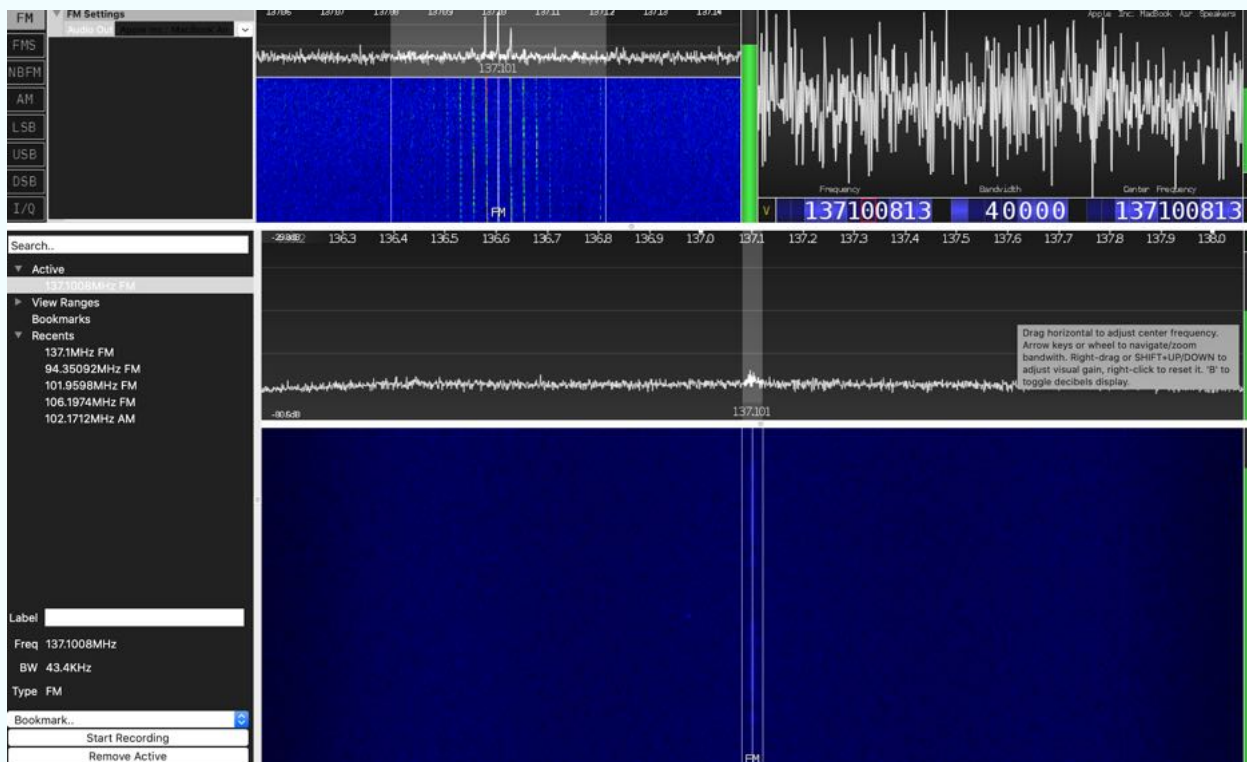


Or, click on the lower waterfall.

Begin typing a number. A pop-up window will appear. Complete typing the frequency you want and, on your keyboard, press Return. Remember, the default unit is Megahertz, always written as MHz. Megahertz is a unit of frequency equal to one million hertz.



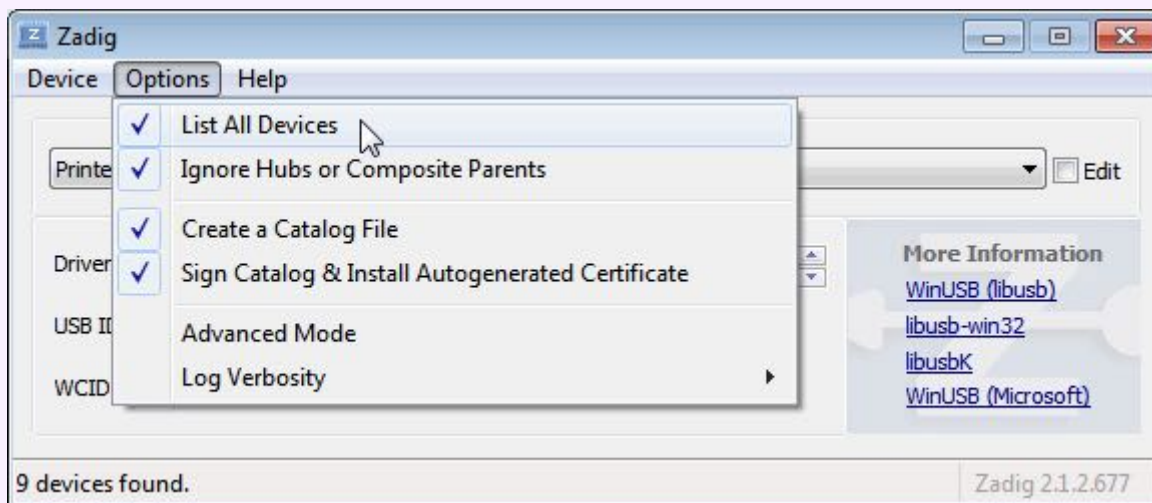
6. To change "Modulation type" or modes, on the top left select AM, FMS, NBFM, AM, LSB, USB, DSB, I/Q. NOAA satellite transmissions are FM, which is the acronym for Frequency Modulation.
7. Adjust the bandwidth. Under the label Bandwidth, click on the upper and lower parts of the numbers.
8. Adjust the audio output volume. In the top left, click and drag the vertical green bar.
9. **Set the Recording Path** for the audio recording that you will make of the satellite pass. Go to Recording >> Set Recording Path. You cannot make an audio recording before setting the recording path.
10. Optional: Practice tuning to different frequencies and using different kinds of modulation:
  - 101 Mhz: FM Broadcast Radio
  - 800 kHz: Long Wave AM Radio
  - 17 Mhz: Amateur bands
  - 137 Mhz: VHF



Screenshot of CubicSDR while NOAA-19 is just beginning to appear. Notice faint dashes and dots in the upper waterfall.

## Windows OS

1. Assemble your antenna and connect your antenna to your RTL-SDR dongle. Plug your dongle into a USB port in your laptop.
2. Open Zadig.
3. In Zadig, go to "Options->List All Devices" and make sure this option is checked. If you are using Windows 10, in some cases you may need to also uncheck "Ignore Hubs or Composite Parents".

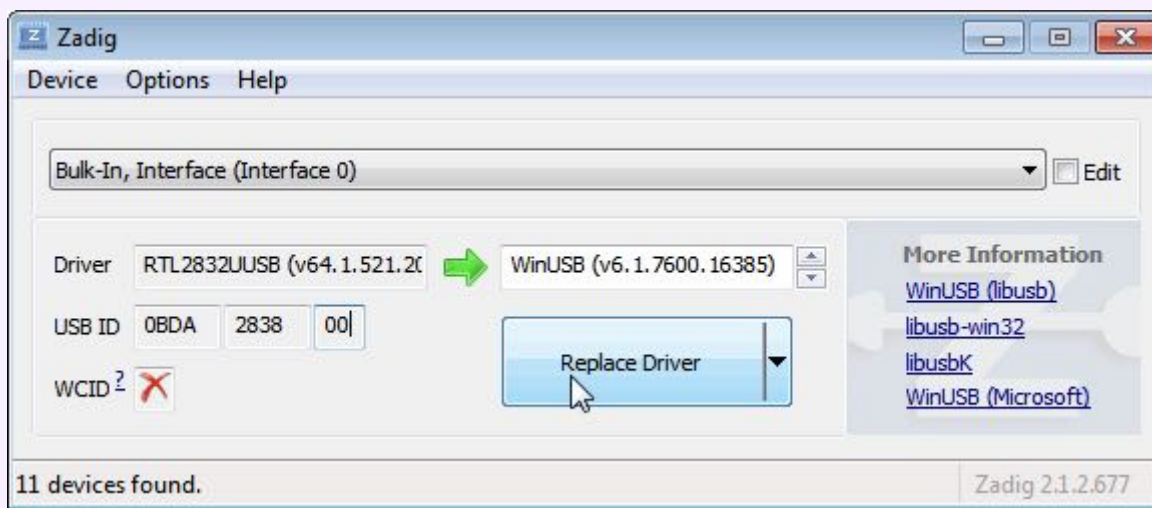


4. Select "Bulk-In, Interface (Interface 0)" from the drop down list. Note on some PCs you may see something like RTL2832UHIDIR or RTL2832U instead of the bulk in interface. This is also a valid selection. Double check that USB ID shows "0BDA 2838 00" as this indicates that the dongle is selected. If you have a choice between 'Bulk-In, Interface (Interface 0)' and 'RTL2832UHIDIR', but only 'Bulk-In, Interface (Interface 0)' shows the correct USB ID (0BDA 2838 00) choose 'Bulk-In, Interface (Interface 0)'.

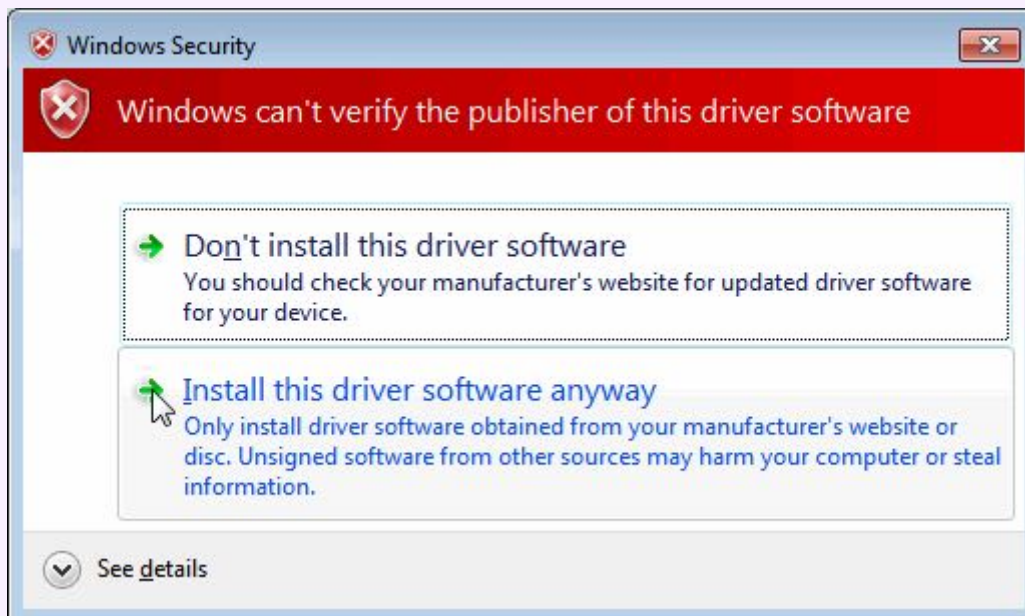
**WARNING: DO NOT** select anything else or you will overwrite that device's driver! **DO NOT** click around randomly in Zadig. If you do you are likely to overwrite your mouse, keyboard, printer, soundcard etc drivers. Many bad reviews we get are due to people clicking around randomly in Zadig, so **PLEASE** check what you are doing first.

5. We need to install the WinUSB driver, so also ensure that WinUSB is selected in the box after the green arrow (this is the default selection). Double check all the text as shown in the image below. If you are installing your RTL-SDR dongle for the first time, the box next to the word 'Driver' may say 'None' because no drivers have been installed yet. That's completely fine.





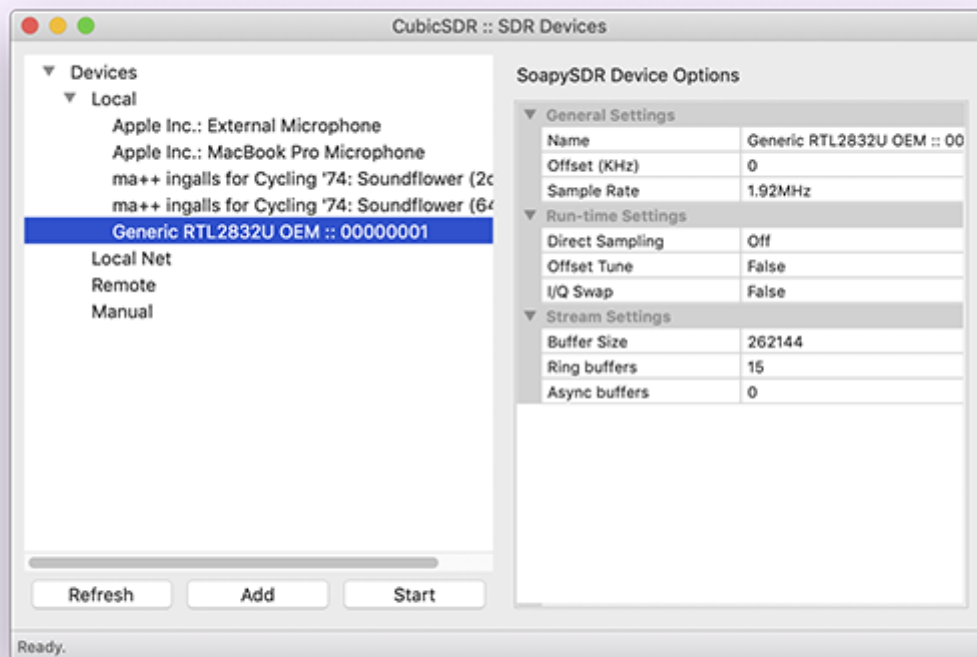
6. Click 'Replace Driver' or 'Install Driver'. On some PC's you might get a warning that the publisher cannot be verified, but just accept it by clicking on "Install this driver software anyway". This will install the drivers necessary to run the dongle as a software defined radio.<sup>2</sup>



7. Exit Zadig and launch CubicSDR. Make sure your RTL-SDR dongle is still properly plugged into a USB port on your laptop.

8. In the dialog window select your dongle from the Devices list and click Start. For the RTL-SDR dongle select "Generic RTL2832U OEM :: 00000001".

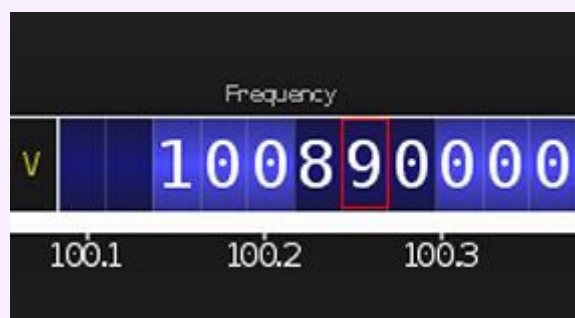
<sup>2</sup> Steps 3-6 are sourced from the RTL-SDR quick start guide: <https://www.rtl-sdr.com/rtl-sdr-quick-start-guide/>



9. To check CubicSDR is working, click anywhere on the top waterfall window. You will hear static / radio noises and see the waterfall moving.

10. Tune to a frequency. There are several easy ways to tune to a frequency in CubicSDR

Under the label 'Frequency', click on the upper and lower halves of the numbers. This will change the numbers and thus the frequency you are listening to.



Or, click on the lower waterfall.

Begin typing a number. A pop-up window will appear. Complete typing the frequency you want and, on your keyboard, press Return. Remember, the default unit is Megahertz, always written as MHz. Megahertz is a unit of frequency equal to one million hertz.



11. To change "Modulation type" or modes, on the top left select AM, FMS, NBFM, AM, LSB, USB, DSB, I/Q. NOAA satellite transmissions are FM, which is the acronym for Frequency Modulation.
12. Adjust the bandwidth. Under the label Bandwidth, click on the upper and lower parts of the numbers.
- 13 Adjust the audio output volume. In the top left, click and drag the vertical green bar.
14. Set the Recording Path for the audio recording that you will make of the satellite pass. Go to Recording >> Set Recording Path. You cannot make an audio recording before setting the recording path.
15. Optional: Practice tuning to different frequencies and using different kinds of modulation

## BONUS!

Frequency Mode		Band Content	
101 MHz	FM	VHF	FM broadcast frequencies
7 MHz	FM	HF	40 m amateur bands – also known as shortwave
800 KHz	AM	MF	AM broadcast frequencies

## Bands

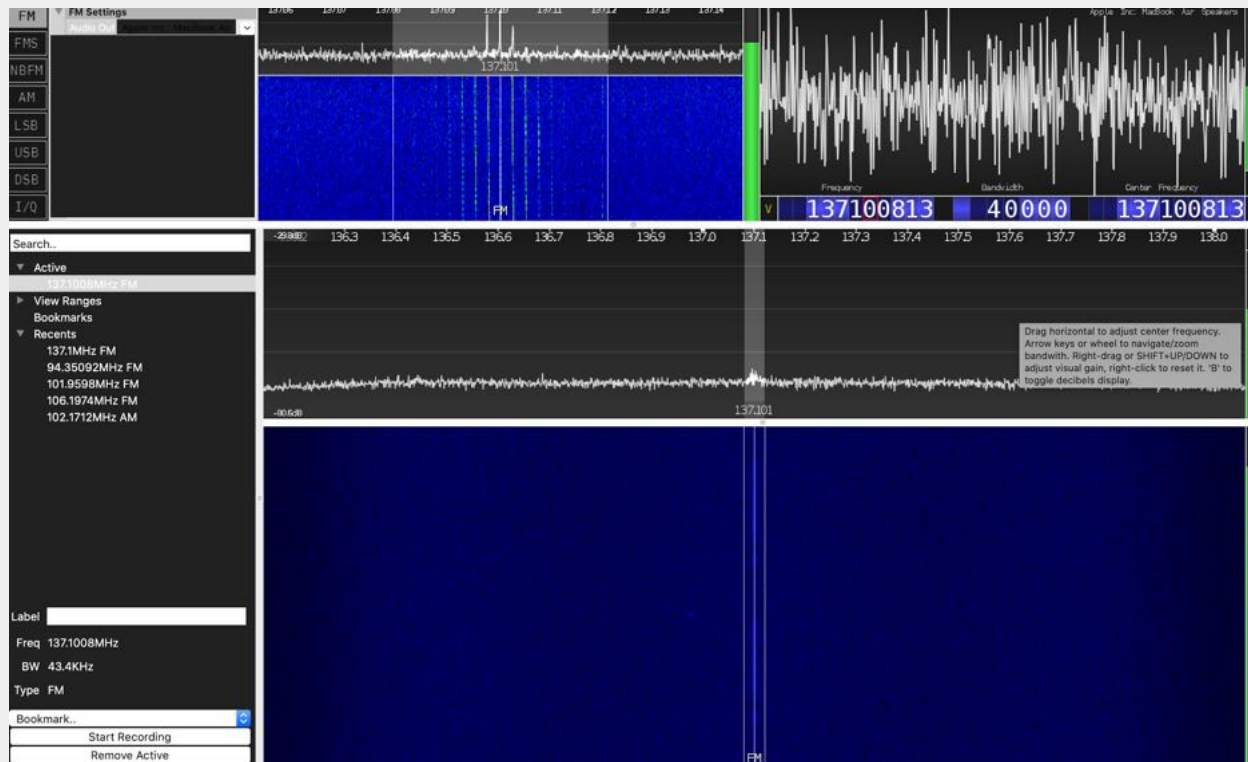
MF (medium frequency) - 300 KHz - 3 MHz

HF (high frequency) - 3 MHz - 30 MHz

VHF (very high frequency) - 30 MHz - 300 MHz

UHF (ultra high frequency) - 300 MHz - 3GHz





Screenshot of CubicSDR while NOAA-19 is just beginning to appear. Notice faint dashes and dots in the upper waterfall.

## CubicSDR settings for receiving a NOAA satellite

Other than setting up your antenna, linking your antenna to your computer and starting CubicSDR as explained in the previous section, there are **three key CubicSDR settings** you need to remember for recording NOAA satellite transmissions.

### Frequency

You always need to tune to the frequency of the NOAA satellite you are trying to capture

NOAA 19 = 137100000

NOAA 18 = 137912500

NOAA 15 = 137620000

### Bandwidth

Keep this at 45000 Hz to select the breadth of the satellite signal.

### Modulation or Mode

Always select 'FM' as your mode for capturing NOAA satellite signals.

## Pre-satellite pass checklist

- Is your antenna built up correctly?
  - If using a v-dipole
    - the metal dipoles are 54.5 cm
    - the dipoles are 120 degrees apart
- Is your antenna linked to your dongle, and is the dongle plugged into a USB port?
- Are you tuned to the correct frequency of the satellite?
- Are you using a 45,000 KHz bandwidth?

- Are you demodulating the signal with FM?
- Do you understand how to start and stop the audio recording?
- If using a turnstile antenna, do you know which direction the satellite is coming from?

## **Receiving your first NOAA satellite pass**

1. Set up your antenna using the Antenna Assembly and Set-Up instructions. Link your antenna to your dongle to your laptop. Launch CubicSDR and tune to the frequency of the NOAA satellite. Input the correct bandwidth (45000) and make sure that 'FM' is selected as your mode.
2. The satellite signal looks like a faint series of dots and dashes that will begin to appear on the waterfall display of your CubicSDR software around two or three minutes after the pass officially begins. It sounds like a ringing tone with some distinctive 'tick tocks' about every 0.5 seconds.
3. When the audible signal becomes relatively clear, click "start audio recording" in the lower left hand corner of the CubicSDR interface order to start recording the sound / data of the satellite and save it for processing later.
4. Listen! The clarity and precision of the satellite sound will tell you a lot about how well you are receiving the pass, and how well you are pointing the antenna (if using a turnstile).
5. If you are using a Turnstile antenna, remember to track the satellite as it orbits overhead. If you are using a V-Dipole, you don't need to adjust the antenna throughout the pass.



Curator Olivia Berkowicz and artist / biophysicist Aouefa Amoussouvi track a NOAA satellite at Akademie Schloss Solitude, Stuttgart, 2021. Source: open-weather

6. Once the pass is over (when the sound of the satellite fades into static) “stop the audio recording” by clicking the same button you used to start it. The WAV file will be automatically saved in the folder where you ‘set the recording path’. Now you have saved the satellite transmission and you can decode it into an image!

## Set up for first satellite pass (30 min)

A satellite pass should be programmed in the day by workshop leaders! 🧑🏫📡

## Satellite image decoding (30 min)

Congratulations! You now have a WAV file saved on your computer. The WAV file contains the 2400 Hz amplitude modulated (AM) signal that sonically carries the information that will compose the image.

What tools can you use to process the WAV file into an image?



## Web apps and software

### open-weather apt

In collaboration with Bill Liles and Grayson Earle, open-weather recently launched a new, accessible, online decoder for NOAA satellite images. You don't need to install it, simply go to: <http://apt.open-weather.community>

### APT 3000

Open-weather apt is forked from [APT 3000](#), another browser-based decoder, though with less features.

There are many other advanced satellite signal decoders that enable you to add colour to your image, add a map overlay, and play with the sensor data.

### Installing software on your laptop (not covered in the workshop)

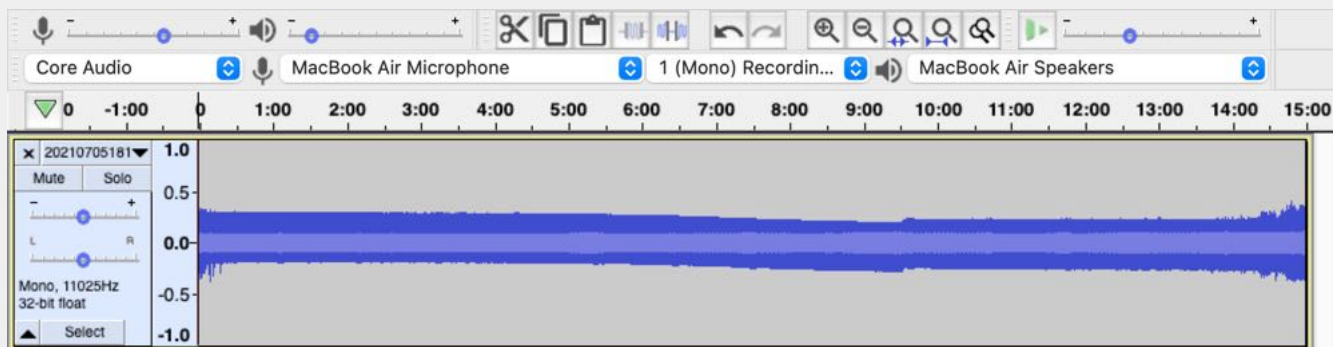
[WXtolmg](#) is a powerful software for satellite signal decoding. It enables a high level of processing of imagery. However this is a closed source, outdated software, and it will only work on Windows OS or Mac OS up to Mojave (not Catalina or Big Sur).

- WXtolmg for Windows: Download [here](#)
- WXtolmg for Mac up to Mac OS Mojave: Download [here](#).

[NOAA APT 1.3.0](#) is an open source satellite signal decoding software that enables colour enhancements and map overlays. It was created by open source programmer Martin Bernardi and collaborators. NOAA APT 1.3.0 is the only advanced satellite signal decoding software available for Macs running Catalina and Big Sur. However it cannot be directly downloaded. Rather it is necessary to 'compile' the software by putting code into the Terminal application of your Mac. It takes about 30 minutes to compile NOAA APT 1.3.0 on a Mac running Catalina or Big Sur. It's fun!

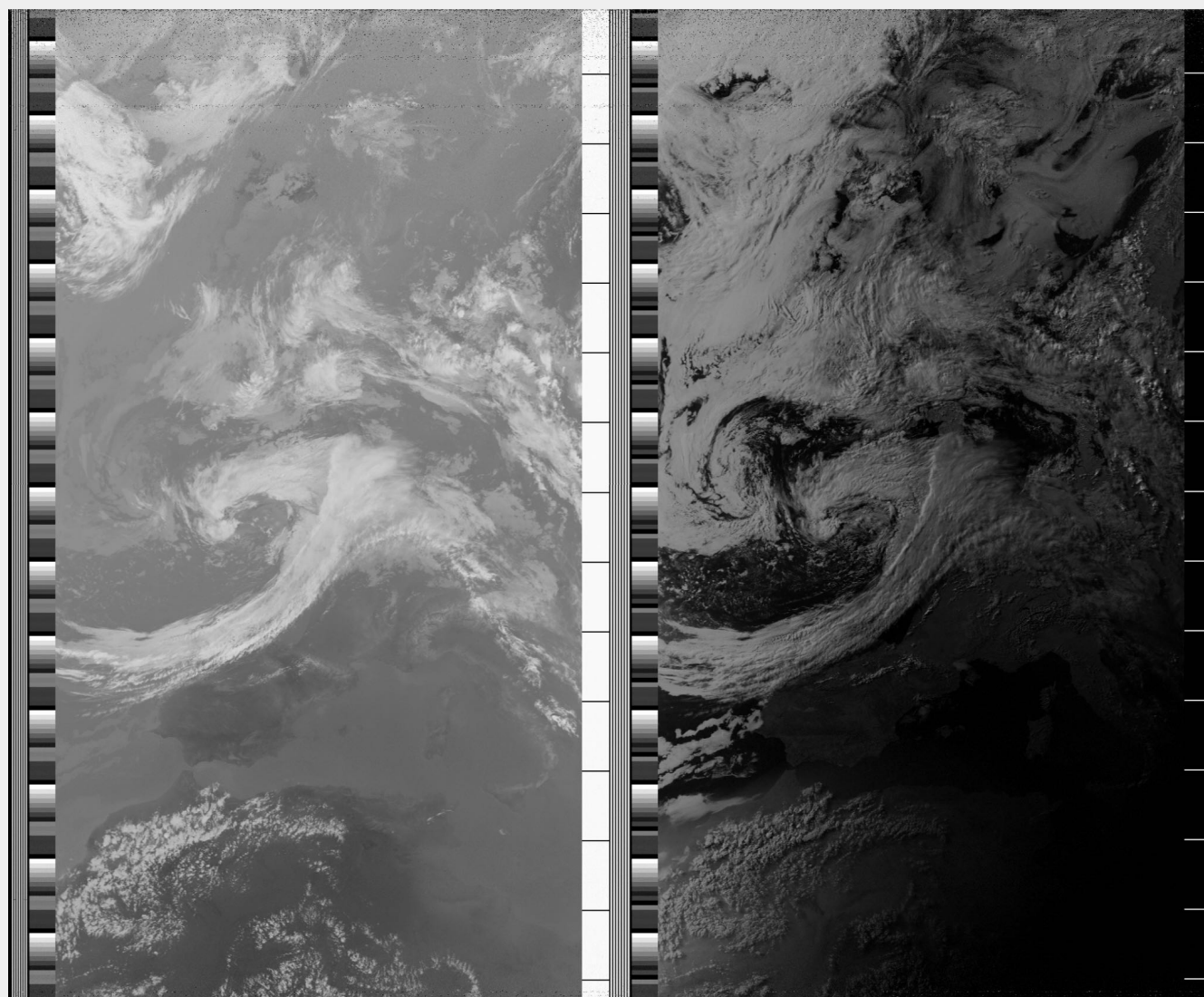
See the open-weather guide 'How to Compile NOAA APT 1.3.0 on Mac OS' [here](#).

## Resampling your NOAA Audio Recording



In order to use on of the web apps or software listed above, you first need to resample your WAV file using Audacity:

1. Locate the WAV file that you recorded during the satellite pass.
2. Open the file with Audacity.
3. In the lower left hand corner, change the project rate to 11025 Hz.
4. Go to Tracks >> Resample.
5. In the dialogue box, choose 11025 and then 'Resample'.
6. After a couple seconds the track will be resampled.
7. Go to File >> Export >> WAV and export the resampled audio file in 16 bit WAV format to your chosen destination. Remember to add something like 'Resampled' to the file name and '.wav' at the end so that it saves as a WAV file.



## Decoding your NOAA Audio Recording

Now that you have resampled the WAV file you recorded during the satellite pass, you can translate or decode it into an image. There are many different tools that you can use. Different software options were listed above in the section **'Web apps and software'**

The simplest and quickest way to find out what you have captured is to use open-weather apt, an accessible online satellite signal decoder, through your favourite browser.

- Go to <http://apt.open-weather.community>
- Upload your 11025 Hz WAV file.
- Select a demodulation method (we recommend trying them all!)
- Click 'decode image' and then choose which channel you want to view (e.g. A, B or AB).
- If your image appears slanted or glitchy, try increasing the number of seconds in the sync search box.

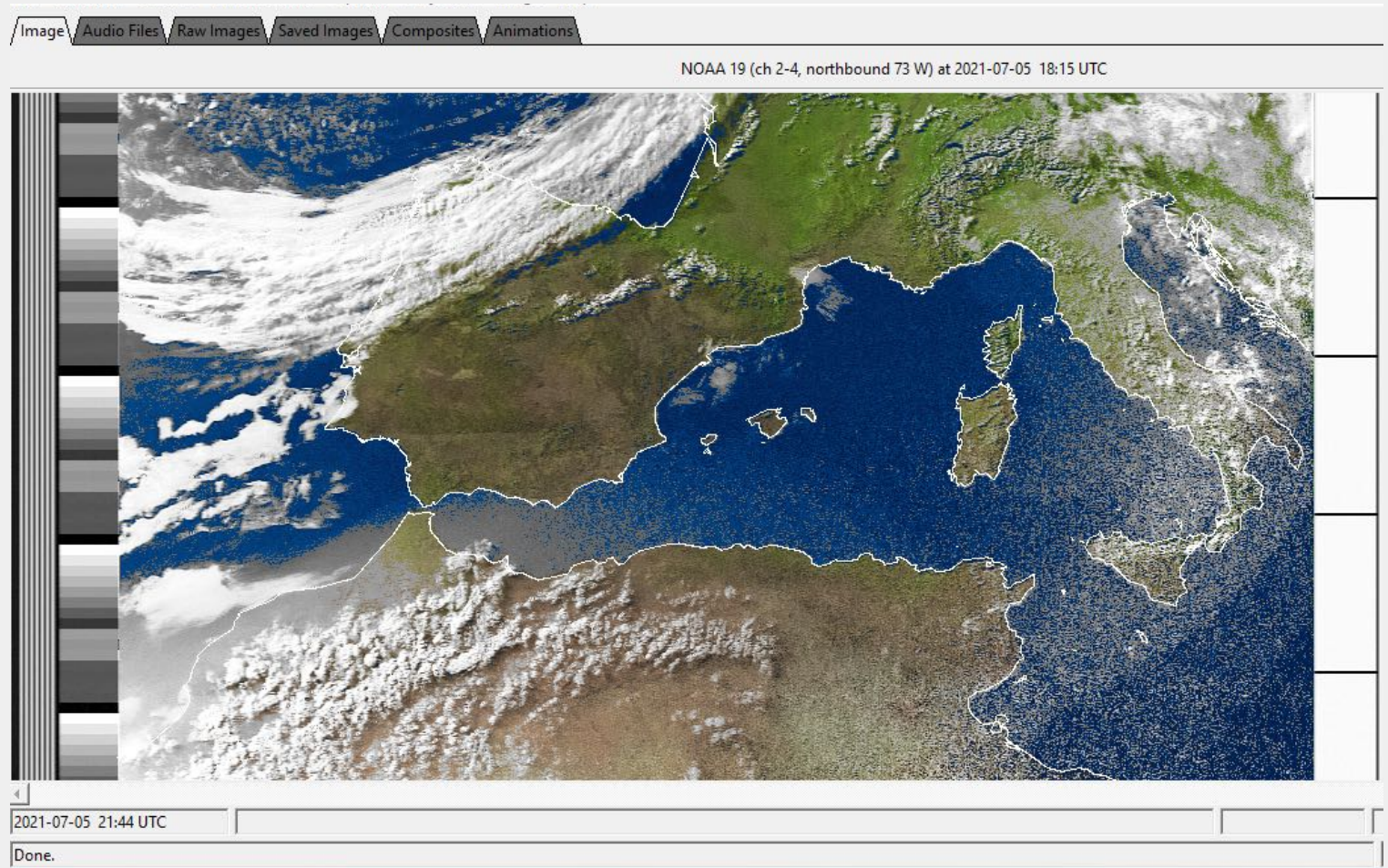
Another browser decoder option is APT 3000: <http://jthatch.com/APT3000/APT3000.html>

Open-weather apt and APT 3000 are wonderful, but they do not support adding a map overlay to your image (yet). See below for examples of satellite images decoded using NOAA APT 1.3.0 and WXtoImg. See the section 'What Software Do I Need?' for more information on these decoders and where / how to get them.

The screenshot displays the NOAA APT 1.3.0 web interface. On the left, the 'Decoding' tab is active, showing settings for 'False color' (with 'Add false color' checked) and 'Orbit prediction' (set to 'NOAA 19'). Below these are sliders for 'Water threshold', 'Vegetation threshold', and 'Clouds threshold'. A 'Process' button is at the bottom of the settings panel. To the right of the settings are two vertical satellite images. The left image is a false-color composite showing land in green, water in blue, and clouds in white. The right image is a grayscale composite showing the same data. Both images show a view of the North Atlantic Ocean with Iceland visible in the upper right.

< July >							< 2021 >						
Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Sun
5	6	7	8	9	10	11	12	13	14	15	16	17	18
19	20	21	22	23	24	25	26	27	28	29	30	31	





*WXtolmg: a closed source, outdated satellite decoder that still works well on older Macs and Windows OS.*

If you are using an older Mac OS system (an OS up to Mojave) or a Windows OS, you can also try 'live decoding' your next satellite pass. Instead of recording the audio of the satellite through CubicSDR, you will 'pipe' the audio from CubicSDR directly to WXtolmg, and WXtolmg will decode the sound into an image in real time. Open-weather have written a simple guide for live-decoding NOAA satellite passes that you can find [here](#).

## Day 02

Second satellite pass (30 min - 1 hour)

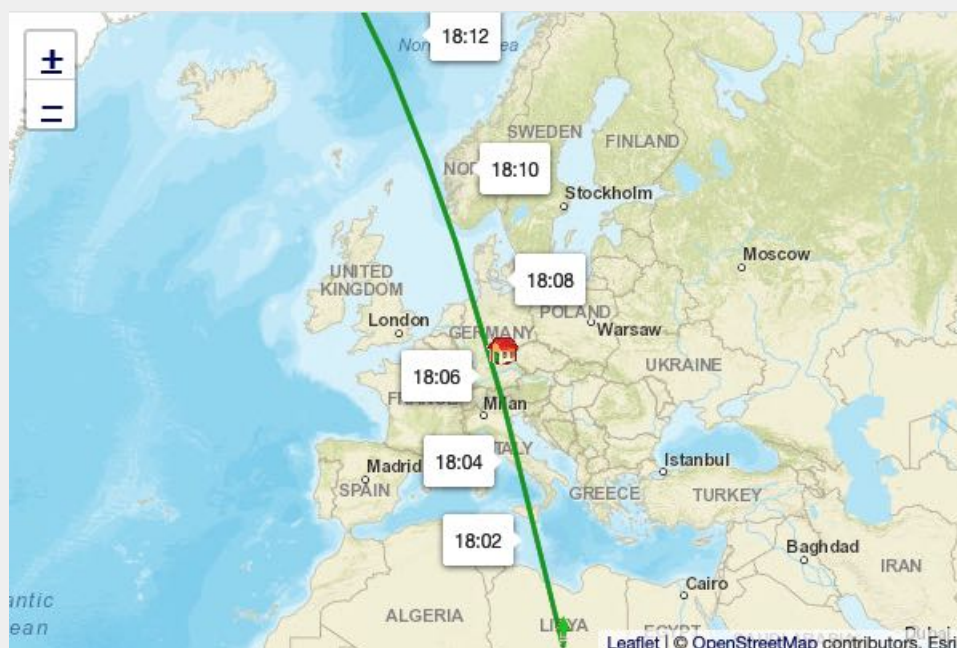
Suggested Break (15 mins)

How can I do this on my own? (30 min)

### Finding a good pass to decode

In this section we will explore how you identify a satellite orbit over your location. NOAA satellites only pass over specific locations for periods of 5-11 minutes at a time. It is important to know when a pass will begin!

1. First, go to <https://www.n2yo.com>; this page will pull your GPS coordinates from your computer's IP address. Take a look at the box in the lower right hand side of the screen under the title 'Your current location'. Are your GPS coordinates correct? If so, you don't need to make an account at this stage. If the coordinates are not correct (the page has not been able to locate your computer) click 'set your custom location' and make a free account. Once you have made an account, input the coordinates of your observing location. For London, the coordinates are: 51.5072, -0.1276
2. In the top menu under "Most Tracked" select one of the NOAA satellites. Currently, NOAA 15, NOAA 18 and NOAA 19 in orbit. As an example, let's select NOAA-19 from the list. On the page you land on next, select "10-day predictions".
3. You will now see a list of all NOAA-19 passes over your location for the next 10 days.
4. In the table, take a look at the 'start time' (the time the pass starts), the Max Altitude (at what elevation the satellite will be when it is highest) and the End time (when the pass ends). Take note especially of the number under the column that reads "El". This is the maximum elevation. You are most likely to receive an image from a NOAA satellite when the maximum elevation is above 45 degrees. → Why do you think we selected the 17:41 UTC NOAA-19 satellite pass for today's workshop?
5. If you click the link for 'Map and Details' you can also see a map of the satellite's orbit path.



6. If you cannot find a good NOAA-19 pass over your location, try going back to "Most Tracked" and selecting NOAA 15 or NOAA 18. Then as you did before, click '10 day predictions' to see the orbits of these satellites over your location over the next 10 days.



## Where you set-up your ground station



*M6I0R receives a NOAA pass from Bude, Cornwall, 2019. Source: open-weather*

Can you receive a NOAA satellite signal inside a building? Probably not, unless you are standing on a balcony holding your antenna with a good view of the sky.

The NOAA transmission is best received from a wide open area with a good horizon. This could be a park, a parking lot, a rooftop, a hill, a beach or a balcony (as long as the balcony has a clear view of the path of the satellite)

Take some time to determine the location you will use. Make sure you can comfortably arrange your antenna, cables and the laptop. A blanket or chair is often useful to keep the laptop off the ground.

## Where to buy an antenna or how to make one?

There are several antenna options for receiving NOAA satellite images:

- [Turnstile](#) antenna (£38)

In open-weather we use 137 MHz turnstile antennas from AMSAT UK. However the AMSAT UK online shop is frequently sold out. They can be ordered from the original supplier [Winkler Spezialantennen](#).



- [Quadrifilar Helix \(QFH\)](#)
- [V-dipole](#) or [Double Cross Antenna](#).

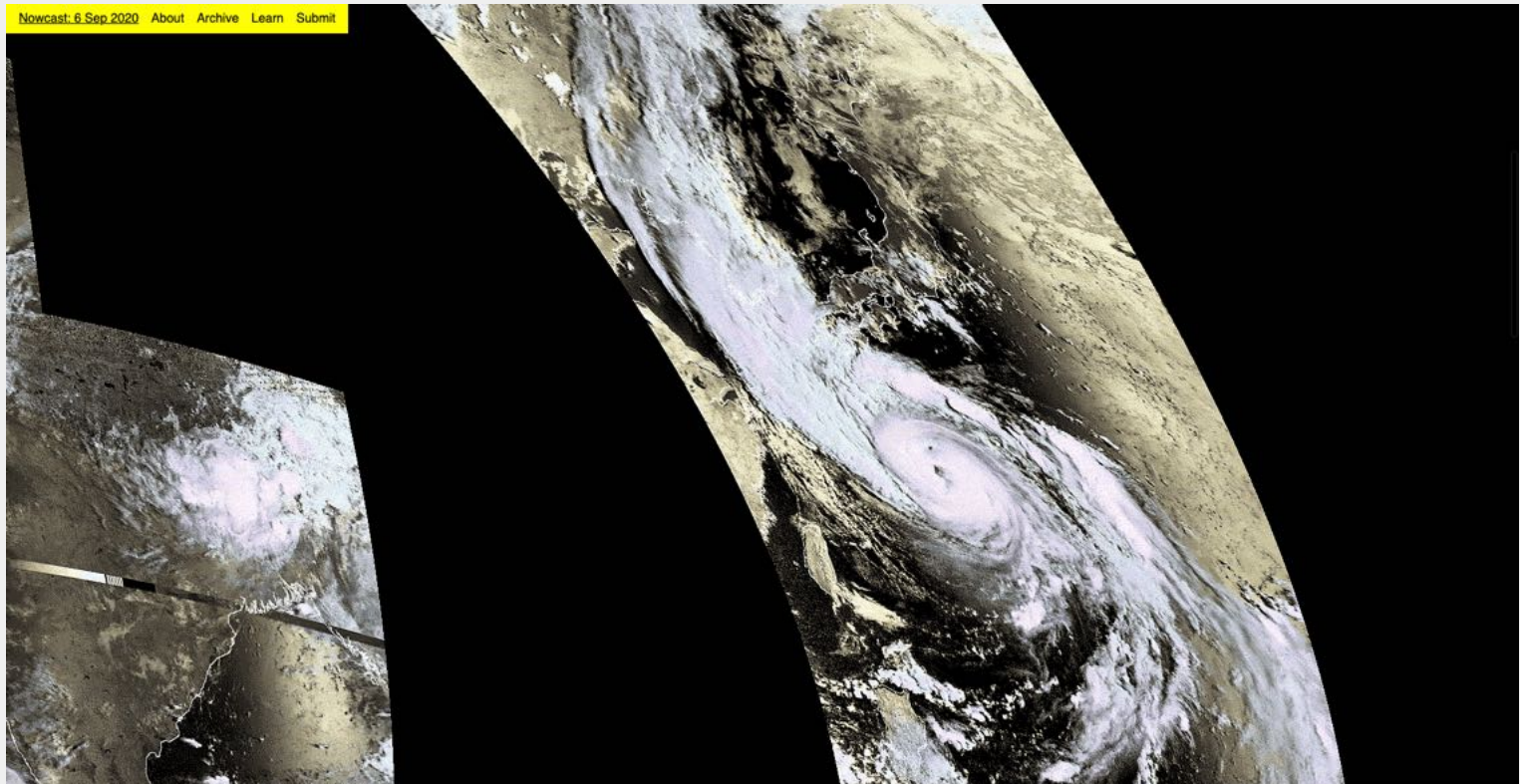
Can I make my own antenna for capturing NOAA images?

Yes! Here are some tutorials:

- How to make [a V-dipole antenna](#)
- How to make an antenna [out of an umbrella](#)
- How to make a [double cross antenna](#)
- How to make a [Quadrifilar Helix \(QFH\) Antenna](#)

## Suggested break (1 hour)

## Open discussion (1 hour)



*First open-weather nowcast, Our Networks, 6 September 2020. Source: open-weather*

## Additional resources

Open-weather is on [Public Lab](#): here we host the [DIY Satellite Ground Station](#) guides, instructions for [compiling NOAA APT on Macs running Catalina and Big Sur](#), and other technical, educational and practical materials. You can 'ask a question' 'write a research note' or comment on open-weather guides and materials to join the dialogue around the project.

Visit: <https://publiclab.org/wiki/open-weather>

To read our feminist principles and how they inform the practices in open-weather, check out the Open-weather Feminist Handbook:

<http://almanacprojects.com/public-programme/open-weather-feminist-handbook>

RTL-SDR Blog: This is a great resource for updates on all things related to software defined radio, including how to receive different meteorological satellites (Meteor M-N2) and geostationary satellites like GOES-13.

<https://www.rtl-sdr.com/>

APT Group: Facebook group with 3-4k members where you can post questions or problems and get answers:

<https://www.facebook.com/groups/Satellite.apr.group>

