Earth Observation Data Visualisation Good Practice Guide

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EUMETSAT and contributors

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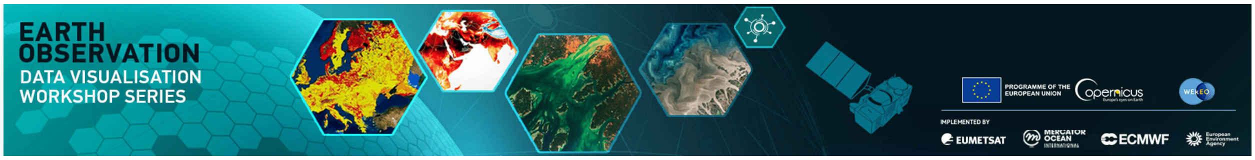
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CHAPTER ONE

EXECUTIVE SUMMARY

The following points summarise the main messages of the guide.

- **Crafting Impactful Stories:** Earth observation data can be a powerful tool for telling compelling stories, especially for environmental issues. It's not just about presenting data; it's about weaving it into a narrative that resonates with people.
- **Versatility of Data:** Earth observation data is incredibly versatile. It can be used to monitor everything from climate change to natural disasters. The guide discusses how this data can be tailored to fit various storytelling needs.
- **Effective Data Visualization:** Successful visualisations move beyond data presentation, and focus on how to make the data understandable and engaging. This includes choosing the right kind of visualization for your audience, whether it's a simple chart for a general audience or a more complex model for experts.
- **Accessing Data:** Practical advice is given on where to find Earth observation data and how to use it. Quick, "off-the-shelf" solutions for those who need information fast, as well as more customizable options for those who need specific types of data are discussed.
- **Audience:** The guide is open-source and invites ongoing contributions from experts in the field. It serves as a one-stop shop for journalists, scientists, and data analysts who want to make complex environmental data accessible and impactful.

CHAPTER

TWO

BACKGROUND

Throughout the spring of 2023, and under the umbrella of the EU's Copernicus Programme, EUMETSAT coordinated a series of workshops focusing on effective ways to visualise Earth observation data. This series brought together ideas and opinions from journalists, scientists and remote sensing practitioners from operational agencies and industry.

The workshops offered advice on how to craft impactful stories using products and imagery derived from satellites, as well as giving practical examples and demonstrations of data use and access.

This document, the Earth observation data visualisation good practice guide, synthesises and summarises the main points of this webinar series, giving examples of effective use of story-telling using satellite data in a variety of contexts.

The guide is by no means a comprehensive overview of all satellite applications, and, given the pace of development in the space sector is unlikely to ever be. It is also not a compendium of all good examples of data visualisation using satellite data, but rather offers representative examples.

However, the project is ongoing, and open, and you should feel free to contribute to it should you have opinions to share, examples to add, or constructive criticism to offer. If you wish to access the primary material used to create this guide, you can find links to the presentations on the *workshop presentation* page, or links to the YouTube videos of the presentations on the *introduction* page.

Note: This project is open to community development. If you wish to contribute to the document or share an opinion on it, we'd love to hear from you. Please consult the *Contribution guidelines* section for information on how you can get involved.

This guide is written using Read the docs. Its source documentation can be found in the following git repository.

For any questions about the guide, please contact ops@eumetsat.int.

CHAPTER THREE

FUNDING

This project was funded by the EU Copernicus Programme and coordinated by EUMETSAT in partnership with ECMWF, Mercator Ocean International and the European Environment Agency.

The webinar series and resulting guide was delivered, under contract to EUMETSAT, by SpaceTec Partners and Innoflair UG.

CHAPTER

FOUR

CONTENTS

4.1 Introduction

While satellite imagery and other products have generally been available since the 1980s, the EU's Copernicus programme has ushered in a new era of freely accessible Earth observation (EO) imagery and data.

Effective visualisation of Earth observation data is increasingly important to help raise awareness of environmental phenomena, extreme weather events and the impact of climate change.

It is also important for accurate communication of scientific results at a time when mis- and disinformation around science and research is becoming more of an issue.

This good practice guide developed initially from a series of six data visualisation workshops that were funded by the European Commission Copernicus programme and organised by EUMETSAT.

The series of six webinars covered a variety of environmental themes and invited contributions from scientists, journalists, and communication experts.

Practical demonstrations of Earth observation data access, applications, and visualisation were also given by various personnel working under the Copernicus programme entrusted entities.

The presentations can be found on a designated playlist on the EUMETSAT YouTube channel, or you can view the first one, below, and follow the links at the end.

https://youtu.be/mDh1Ty_j5KI

Associated slides from the presentation can be found in the designated workshop git repository. You can find links to the individual weeks in the *workshop presentations* section.

This guide is a living resource. We welcome contributions from individuals, journalists and any related initiatives within the Earth observation community.

Please see the *contribution guidelines* for information on how to add to this resource.

4.2 Acknowledgements and authors list

EUMETSAT would like to express its gratitude to all presenters and participants, who attended the initial workshop series, and contributed their presentation content, ideas, and discussion points, which formed the basis of the first draft of this good practice guide.

Contributory authors and links to individual **presentations** are below:

- Aida Alvera-Azcárate - University of Liege, GHER
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- Vittorio Brando - CNR
- Samantha Burgess - C3S
- Cathy Clerbaux - CNRS
- Giovanni Coppini - CMCC
- *Sienna Cumby* - ALSO Space
- Gary Dagorn - Le Monde
- Letizia Davoli - TV2000
- Scott Duncan
- Alexander Epp - Der Spiegel
- Hayley Evers-King - EUMETSAT
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- Clare Nullis - WMO
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- Ivan Smiljanic - EUMETSAT
- Chris Stewart - C3S
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The text in this good practice guide is based on a summary of the extensive contributions made during the EUMETSAT Earth Observation Data Visualisation Workshop, and was developed by the following authors:

- Benjamin Loveday – Innoflair UG
- Hayley Evers-King - EUMETSAT
- Neil Fletcher - EUMETSAT

The source code for this documentation is managed by Benjamin Loveday. For questions about editing and contribution, please see the *Contribution guidelines* section of this guide.

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4.3 Contribution guidelines

This good practice guide is an open community development, licensed under Creative Commons 4.0. We welcome suggested edits and additional content from anyone who would like to contribute.

There are two ways that you can contribute. In both cases you will need to create a GitHub account. Once you have done this, you should find your way to the source repository for this documentation, which can be found at https://github.com/wekeo/eo-data-vis-best-practice-guide. You can find the documentation itself in the *./docs/source* folder. From this point onwards, how you contribute depends on your level of familiarity with git;

1. If you are a GitHub beginner: you can contribute content by raising an "issue" on the top tab, and add the content you would like to change. We will monitor the issues and merge the changes for you once they have been approved.
2. If you are more familiar with GitHub contributions can be made in the form of merge requests. We will review the content prior to accepting the merge request. For guidance on setting up the repository and making merge requests, please see the Read the Docs documentation and general guidance on use of GitHub.

You can access the GitHub source code for any *Read the Docs* page by clicking on the small "pencil" icon on the top of each page. You can then edit and submit a pull request.

Contributors should be careful not to violate the associated terms of the Creative Commons licence, making sure that any material shared (images etc) are permitted to be used in this context, and appropriately attributed. If contributors add new images, they should attribute to themselves and implicitly agree to the resharing of those images under the terms of the license associated with this guide. As far as possible, contributors should seek to work within the currently defined structure of the document, however new sections can be proposed, if they are a significant addition not represented in the current structure. New contributors should add their names to the author list above, with their merge request.

In this guide, we consider what makes a story, told with the use of visualisations of Earth Observation data, impactful. We take a broad interpretation of impactful. Impactful can mean (non exclusively):

- Communicates a challenging topic accurately
- Reaches a large audience, directly, or via multiple platforms
- Reaches an audience that typically does not engage with a topic
- Can be used in an education or training context
- Promotes the application of Earth observation data for societal benefit

This good practice guide covers Earth observation data visualisation in the broadest sense – from single images, through to visualisations created from multiple data products representing complex analysis. This guide also refers to examples beyond computer-based visualisations.

Within the initial workshop, and subsequently within this good practice guide, we have avoided examples relating to human conflict, and in the case of natural disasters, avoid exploiting the event and place a priority on retaining the dignity of those affected.

Contributors should keep the above context in mind when submitting contributions to this good practice guide.

If you have any problems at all with contributing, or wish to discuss the good practice guide with us, please contact the EUMETSAT helpdesk, referencing this webpage and requesting the attention of Hayley Evers-King.

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4.4 What makes a good environmental story for modern news media?

The world is more connected than ever, with media platforms ranging from television, newspapers, and radio, through to online websites, video streaming services, and social media.

Those producing content for media range from journalists and communication experts, through to scientists, and the public.

With this diversity of platforms and voices, the opportunities for telling stories about the planet using Earth observation data are endless.

However, different platforms, audiences, and communication styles, can require quite different approaches if stories are to have impact.

4.4.1 Journalists' perspectives on environmental stories

Journalists are increasingly working with Earth observation data to illustrate environmental stories.

Earth observation offers the opportunity to amaze the public with things they have never seen, to observe extremes, or to be connected to distant places on a daily basis.

Journalists are confident using Earth observation data and as well as visible optical imagery via viewers, many will work with advanced time series data and radar and thermal data to complement articles.

Human interest stories, where Earth observation data can illustrate the scale and extent of impacts of environmental phenomena are, of course, popular. floods, storms, fires, and earthquakes are more and more frequently being illustrated with satellite imagery. Frequently this data is also used directly in these contexts to protect lives and livelihoods, though this is not always included in the media stories.

Further themes for stories involving Earth observation relate to new sensor technology, such as the new lightning imager on the MTG-I1 satellites (BBC News).

Similarly, there is a lot of interest in unusual events or observations such as particularly large volcanic eruptions and icebergs.

Another related aspect that is appealing in the media, is visualising change. Earth observation data can be used to provide before and after data associated to rapid changes e.g. in glaciers or lakes, or as a result of human actions. Whilst appealing these stories are approached by thorough journalists with caution, to ensure that change is communicated in the appropriate context.

Examples of some of these stories can be found in the *example stories* section of this good practice guide, and recommendations on what makes a good Earth observation data visualisation for journalists can be found in the *What makes a visualisation..?* section.

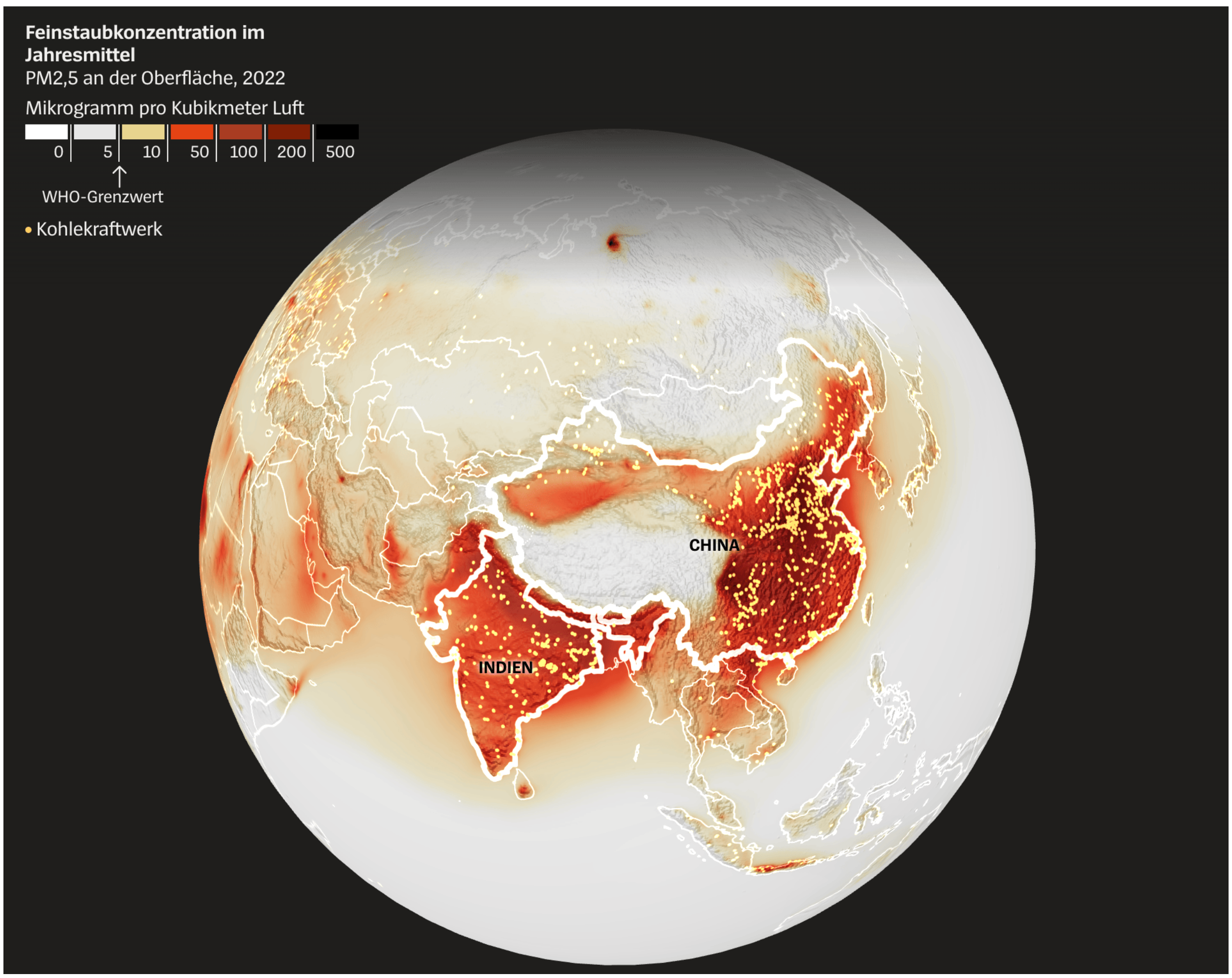

Fig. 1: *Global air quality; particulate matter concentration (Credit: Der Spiegel)*

Fig. 2: *Floods in Pakistan from Copernicus Sentinel-2 (Credit: Le Monde, Copernicus)*

4.4.2 Telling stories on social media

With the availability of social media, the opportunity has arisen for almost anyone to tell stories to almost anyone else. A variety of platforms exist, offering different formats to share data visualisations including images, videos, and text of varying length and style.

The huge userbase for social media content means that there is great potential to reach large audiences, however storytelling through these platforms often comes with challenges.

Social media can be used to spread misinformation, and visualisation can be taken out of context. As such, the need to be clear and accurate with visualisations is ever more important.

Many forms of visualisation can be successful on social media, including those which are more interpretive, or fun.

Social media can be a very effective medium to reach new audiences and raise awareness of the Earth observation sector and the data that are available.

Earth observation offers incredible opportunities for creativity, and sharing awe and wonder, and quickly raising awareness of topical environmental issues.

Social media also allows networking in support of storytelling. Journalists can use social networks to find experts to support visualisations and provide expert perspectives on environmental phenomena. Journalists also use social media to promote their content to large audiences.

The examples below show how satellite data can be used on social media to highlight events and also link to on-the-ground events. This can be done at varying scales (e.g. global, wildfires, algal blooms)…

Using satellite data in this way can push stories into communities that they would not otherwise reach.

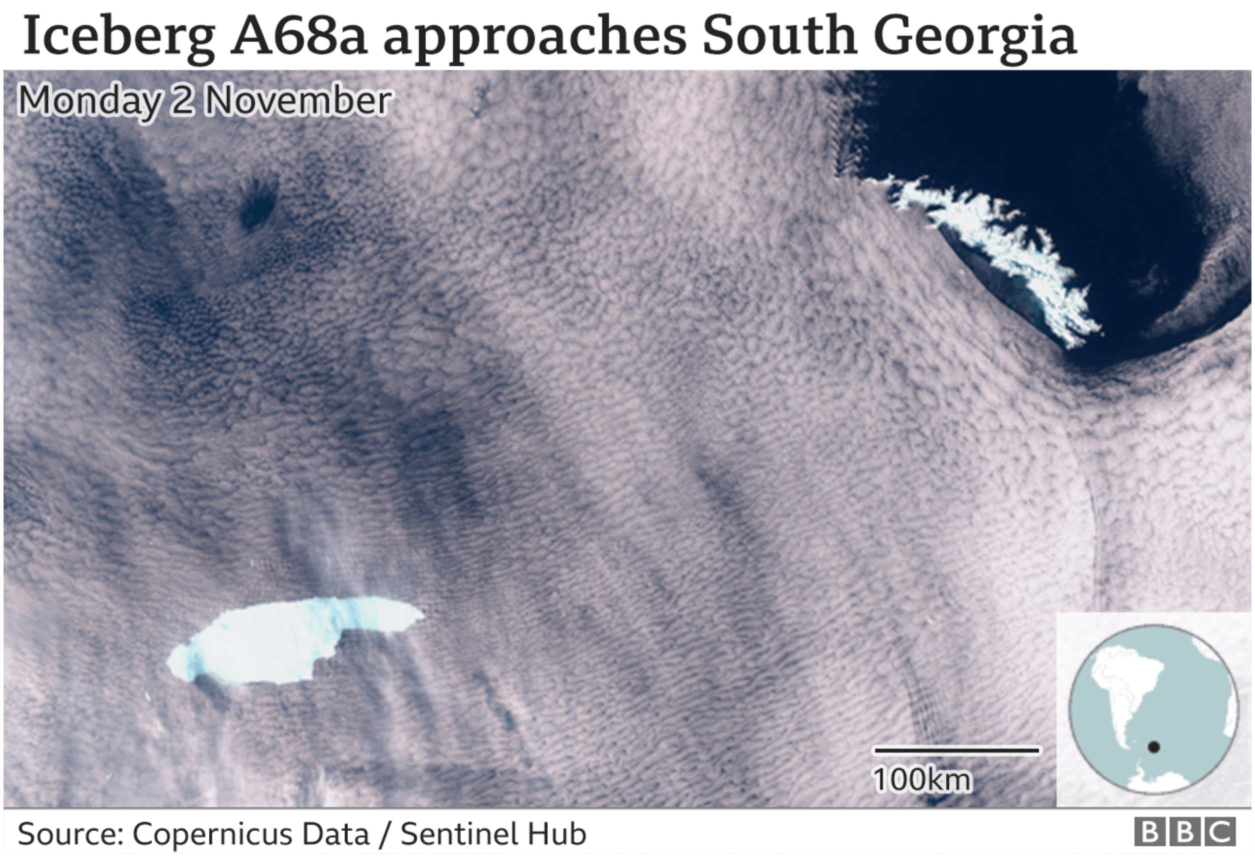

Fig. 3: *Following the trajectory of the A68a iceberg with Copernicus Sentinel-3 OLCI (Credit: BBC)*

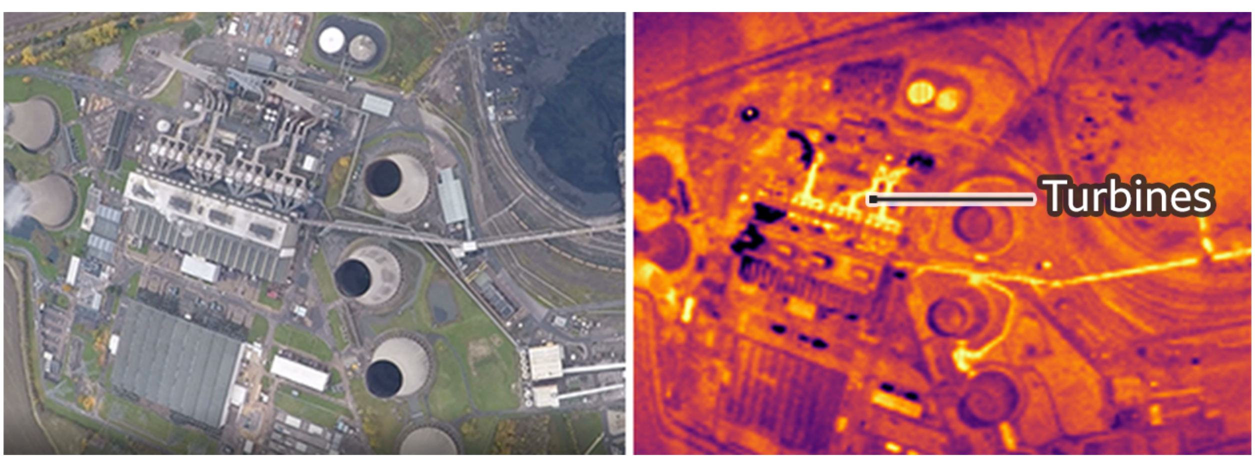

Fig. 4: *Mapping industrial activity in the infra-red with HotSat-1 (Credit: BBC)*

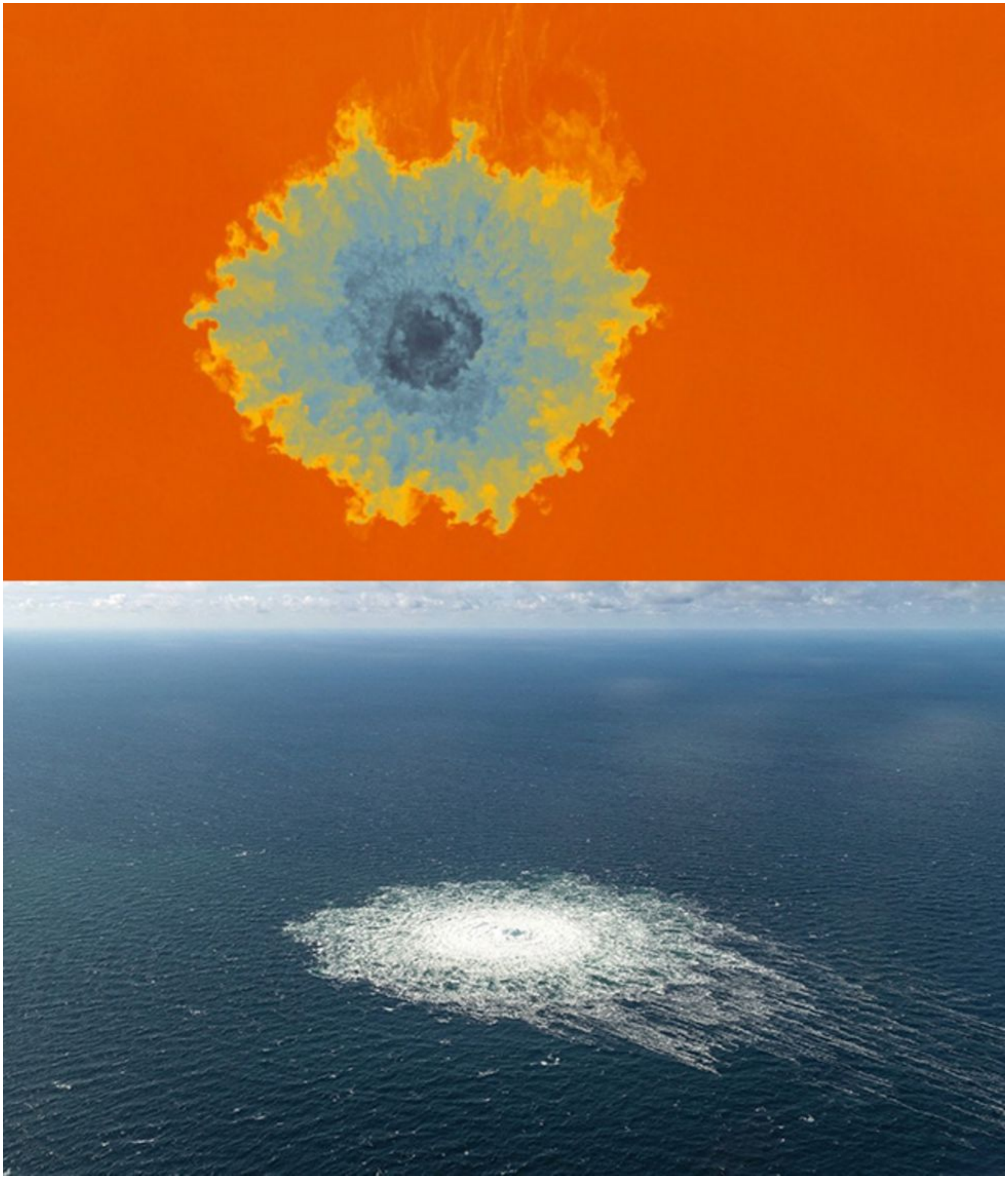

Fig. 5: *Capturing the Nordstream pipeline leak in the infra-red with HotSat-1 (Credit: BBC)*

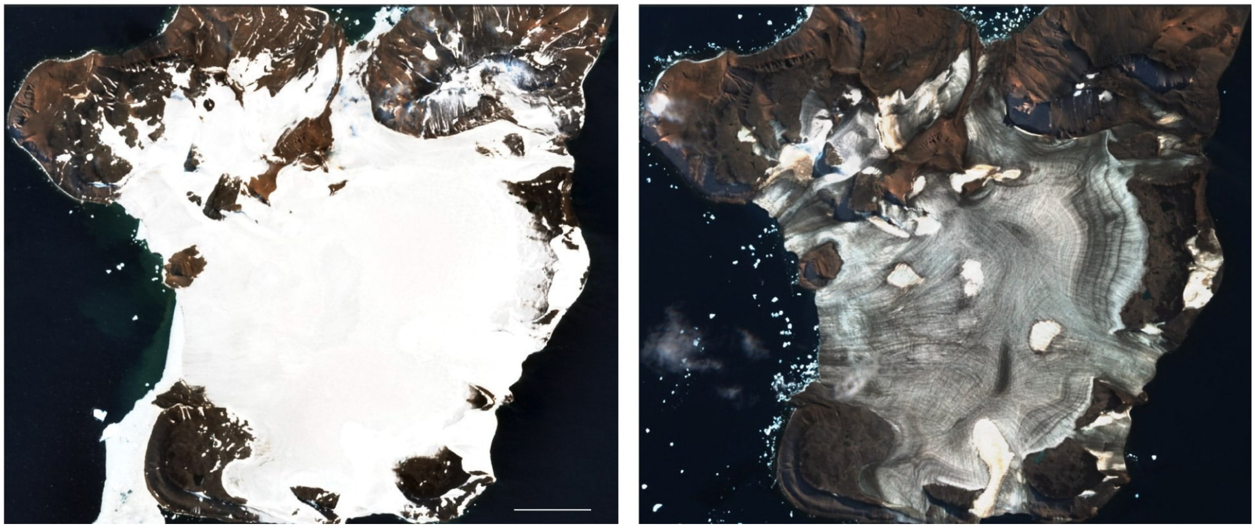

Fig. 6: *Mapping glacial coverage with Copernicus Sentinel-2 (Credit: Washington Post)*

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4.4.3 Communicating science

Modern media offers huge opportunities for science communication to very broad audiences.

The role of communicating science is increasingly being taken on by scientists because of their passion for sharing knowledge and also as a requirement to publicise their research activities.

Scientists communicate their research through blogs and articles or social media posts, or through interviews with the mainstream media.

Efforts by scientists to communicate Earth observation research can bring a number of benefits including:

- Promotion of research (i.e. journal articles) to wider audiences.
- Establishment of scientists as role models for future generations, helping to create a feeling of participation and ownership - showing that science is part of society.
- More credible scientific voices on environmental and climate issues to counter the rising issue of misinformation.
- Creation of cross-disciplinary collaboration between scientists themselves.
- Engagement with journalists who can then accurately tell stories to even wider audiences.

In the Earth observation sector, greater engagement with the media can help to:

- Show the relevance of Earth observation data to current news: satellite imagery nearly always has something to add to a news story, whether it's an aerial view of a big cultural event, or a beautiful environmental phenomena.
- Make scientists more approachable. Sharing challenges and facets of day-to-day life, can help foster engagement, reducing 'ivory tower' feelings around science.

4.5 What can Earth observation observe?

Modern Earth Observation by satellites provides measurements that can support our understanding of nearly all aspects of the Earth system. From topics affecting land, to oceans, our atmosphere to ice, short term weather, and long term climate; satellite data has something to say about the status of the parts of our planet upon which we depend.

Active and passive remote sensing techniques provide numerous ways to observe these systems. A huge array of products is available, at various temporal and spatial scales. Selecting the right product can be a challenge, however support is offered by data providers through guiding documentation, example case studies, tools, and expert user support.

A full breakdown of Earth Observation measurement techniques and applications is beyond the scope of this document, but the subsections below summarise some key application domains covered by this data, with relevant cross-over indicated.

4.5.1 Land

Satellites can measure key physical aspects of land such as movement (via Synthetic Aperture Radar (SAR)) and temperature (via radiometry).

These can variably be used to understand the impacts of earthquakes, landslides, shoreline erosion, as well as effects of weather and climate on land temperature and soil moisture.

Land use can also be monitored effectively using satellite data, showing changes to buildings, cultivated land, and natural environments (due to deforestation for example).

Optical imagers can capture significant events happening on land, such as issues affecting infrastructure (roads, bridges, ports, canals etc).

Thermal hotspots can identify fires, as well activities on land such gas flares and solar farms.

For example visualisations, with discussions, see the *air quality and wildfires visualisations* section.

To access Copernicus land data please visit the Copernicus Land Monitoring Service.

4.5.2 Atmosphere

Satellite measurements of the atmosphere can tell us about the way it moves and what it is composed of. This provides important information towards understanding weather and climate, but also for a wide variety of topics including air quality, impacts of dust, greenhouse gas and volcanic emissions, and wildfires.

For example visualisations, with discussions, see the *air quality and wildfires visualisations* section.

For access to Copernicus atmosphere data please visit the Copernicus Atmosphere Monitoring Service.

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4.5.3 Oceans

Being vast and frequently inaccessible, oceans are arguably most effectively monitored using satellite data. Physical and biological related measurements of the ocean can provide holistic views on how they function.

Sea surface temperature

Satellites can measure ocean temperatures, supporting understanding of climate change and episodic heatwaves, and providing a core measurement for assimilation into weather forecasting and climate models.

Sea surface height

Ocean height measurements from altimeters provide insight into sea level rise, ocean currents, waves, and winds over the sea. This data can tell stories of slow climate change, natural oscillations, as well as extreme events related to storms etc.

Ocean colour

Insight into ocean biology can be gained from measurements of ocean colour from space. Ocean colour provides a view on any substance that substantially alters the colour of the surface ocean waters. In most of the ocean this is phytoplankton - the base of much of the marine food web, also playing a substantial role in oxygen, carbon and other chemical cycles.

Ocean colour frequently shows the biological response of the ocean to its physical behaviour. Also observable from the ocean colour, are changes in sediments in the ocean, impacting coastal environments. Combined, ocean colour parameters can provide useful information for a broad variety of applications around the topic of water quality.

For example visualisations, with discussions, see the *oceans and sea ice visualisations* section.

Get ideas on how to access and work with ocean data.

For access to Copernicus ocean data please visit the Copernicus Marine Service.

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4.5.4 Cryosphere

A variety of Earth Observation measurement techniques are employed to observe the Earths icy environments. Data from SAR and radiometric instruments can be used to observe ice and its characteristics both on land and sea. Sea ice presents challenges for marine navigation and safety, with observations of floating ice key to many operational oceanographic services in polar regions. Changes in ice, both on land and sea are also a key part of the story of climate change, with both event scale changes (e.g. large iceberg calving and ice sheet collapse) and seasonal trends of interest.

For example visualisations, with discussions, see the *oceans and sea ice visualisations* section.

4.5.5 Weather

The story of Earth observation really begins with weather.

The impact that weather has on our day-to-day lives makes it both a natural priority for satellite measurements, but also for storytelling.

Satellite measurements, such as humidity and temperature, play an essential role in numerical weather prediction for the provision of forecasts at daily and seasonal scales and to issue warnings of extreme weather.

Data from satellites can also provide excellent visual context for reporting on weather events, showing the scale of impacts of storms, fog, rain and snow, and other phenomena.

New satellites such as EUMETSAT's MTG-I1 can also provide information on lightning.

For example visualisations, with discussions, see the *climate and weather visualisations* section.

To access weather data please visit EUMETSAT.

4.5.6 Climate

The topic of climate covers long term variability and changes in many aspects of the Earth system.

Satellite data records are constantly growing, providing time series of measurements of many essential climate variables. From sea-level rise, to ice melting, heatwaves on land and sea, drought and flooding, and extreme weather events; a growing array of climate data records can provide the necessary long-term context for climate related stories.

For example visualisations, with discussions, see the *climate and weather visualisations* section.

To access Copernicus climate data please visit the Copernicus Climate Change Service. EUMETSAT also has long time series of satellite observations dating back to 1978.

4.6 What makes a visualisation…?

Whilst Earth observation data is more available than ever, there are challenges to accessing it, using it, and most importantly in the context here – visualising it. Regardless of the particular topic, we can summarise some major aspects to consider about what makes a successful visualisation.

4.6.1 …clear and understandable?

Labels

Any visualisation should be clear and legible i.e. produced at a high resolution with any text large enough for reading, however further elements of legibility can be underestimated, particularly when visuals are used in different contexts.

Beyond text, other labelling can make images more clear and understandable. Features of interest can be directly labelled, clearly indicating what a reader's attention is being drawn to.

Features in an image may be obvious to an Earth observation scientist or even someone familiar with the story in question, but they may not be obvious to someone without this background and/or someone seeing an image for the first time.

Clear labelling of data sets used (and links to them), and use of plain text explanation of variables (rather than sector specific jargon) can also make understanding visualisations easier.

Scale

Given how infrequently people view the Earth from space with their own eyes, it can be easy to lose the sense of scale. This is particularly true for images where there are no recognisable features, so clear labelling is important to help provide a visual reference and, in addition, a scale bar can be a helpful addition for clarity.

Scale can also be important when creating visualisations with numerical data. In these instances, it can be helpful to provide context as part of the visualisation (See an example of this in the relative size of ice loss vs cities later in this guide).

Formats

Modern media consumption takes place increasingly through digital media on phones, tablets, and laptops. For visuals to be clear and understandable, they increasingly need work in multiple formats and sizes, in particular on screened devices such as mobile phones.

To make visualisations accessible to more people it is also important to include alternative text in web based visualisations, to support text readers; and to avoid flashing GIF animations. Link text

Colour

Colour schemes can be used to great effect to highlight features in Earth observation data, however they need to be suitable for common visual impairment i.e. colour blindness. Colour schemes can also be more or less intuitive, depending on the particular feature of interest e.g. using red for hot and blue for cold is understandable for most people. However, colour schemes can also affect the interpretation of visualisations so care needs to be taken to choose an appropriate colour scheme.

4.6.2 ...accurate?

Whilst visualisation must be compelling to be impactful, it must also be accurate in order to have the type of impact which is desired.

For example when telling a story about change, visualisations must represent that change **in context**. This is particularly important when we are talking about changes in the context of climate.

Whilst before and after images are often attention grabbing, care must be taken these are appropriate in the individual context. Are those changes 'normal' relative to well understood seasonal or interannual trends? Or are they truly unusual and/or extreme.

Excellent visualisations in these topics often contextualise data from the current time period, against data from a longer time period.

Risk is also a related and challenging concept for visualisation, where appropriate context must be given to inform readers about how likely something is to have happened and/or happen again in future.

Cause?

Attributing cause is a further challenge. Whilst we can address the long-term context of events via use of appropriate long-term records, it can still be challenging to truly say, and then accurately visualise *why* something has/is happening.

Collaboration with experts can help assure that visualisations are using the most suitable data for the story in development, and provide necessary context and caveats that can be added.

Further tips for making accurate visualisations include use of clear but simple labels to provide scale and location information, and the selection of colour scales that show true changes using linear change and contrast in the colours selected.

4.6.3 ...draw attention?

The goal of most story-telling is to gain attention and communicate information to specific audiences.

In general, stories and associated visualisations that draw attention are:

- Topical in that they provide more information about current environmental issues, weather extremes, etc.
- Connected to things that people understand or are concerned about.
- Unusual, rare and/or extraordinary.
- Community oriented - e.g. involve networking and recognise community contributions. Images are more likely to be shared when others are recognised for their contributions e.g. tagging data producers, or software developers on social media posts.

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4.7 Access to Earth observation data and tools for visualisation

A wide variety of ways exist to access and work with Earth observation data for visualisation purposes. Which data access routes and/or visualisation tools an individual chooses will depend on some combination of the following considerations:

- Is an appropriate "off-the-shelf" visualisation readily available through an existing service (quicker/easier/less flexible), or do you need to develop your own approach (slower/more difficult/more flexible)?
- Is a single image enough to illustrate the complexity of the topic, or are a series of images/animation needed?
- Is imagery suitable and sufficient on it's own, or is more detailed data analysis and visualisation required?

Below, we present some visualising approaches that address these considerations, beginning with the most convenient and least complex and proceeding in order of complexity until we arrive at code-based tools that offer unlimited flexibility but require a significant time investment.

4.7.1 Viewers

Viewers are online platforms that show spatial maps or imagery based on underlying data sets.

In general, these maps are based on pre-generated layers and do not show the data itself (e.g. in the case of a Web Mapping Service or WMS).

Many viewers extend their capability to offer either analysis tools to interrogate/manipulate the data, or to customise visualisations. Many also offer links to the primary data itself, allowing you to "quick view" a phenomena, and then retrieve the underlying data for bespoke customisation using your own tools.

- EUMETView and EUMETSAT's Earth view
- IPCC Interactive Atlas
- MyOcean Pro
- Sentinel Hub EO Browser
- KNMI climate explorer
- CMSAF latest image viewer
- Allen Coral Atlas
- Global Fishing Watch
- Ocean Biodiversity Information System Mapper
- NASA Earth Viewer
- Himawari Earth Viewer

4.7.2 Dashboards

Dashboards typically bring together data from various sources to either give an up-to-date snapshot of a region, or show how a system is varying in time. They are often thematic, dealing with a specific phenomena, ecosystem, activity or event.

- OSI SAF sea ice dashboard
- Met Norway Sea ice viewer
- Copernicus Atmopsheric Monitoring Service NRT portal
- Le Monde climate dashboard
- Berliner Morgenpost: Mapping where Earth will become uninhabitable
- Our World in Data

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4.7.3 Software for image generation and analysis

Where "off the shelf" options for data visualisation do not exist, it is often necessary to use specific software packages to generate your own. Below is a list of some of the commonly used open-source software packages for working with Earth observation data.

- SNAP
- QGIS
- Copernicus Marine Service QGIS plugin
- Copernicus Climate Change Service toolbox

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4.7.4 Thematic code based approaches

Developing your own code can be time consuming, but offers the most flexible way of working Earth observation data and opens up a near-unlimited range of options for visualisation. R, and Python are two of the most commonly used open-source languages for geospatial work, and there are a large number of libraries that support working with satellite data in both cases.

Both R and Python are supported by Project Jupyter, allowing them to be used to construct Jupyter Notebooks which facilitate training on using code. The landscape of available code options is ever changing, and publishing a comprehensive list of them here will be immediately out of date.

However, we can recommend some start points.

- A catalogue of Jupyter Notebooks for working with Copernicus marine and atmosphere data can be found in the WEkEO Copernicus DIAS catalog

- If you are working with EUMETSAT data you will find all of our Python based training code on our EUMETLAB GitLab group. This contains a number of repositories containing Jupyter Notebooks showing how to work with our marine and atmospheric composition data.
- Jupyter Notebooks on dust, aerosol and fire detection can be found on the EUMETSAT TrainHub portal.
- The SatPy python package offers extensive options for data visualisation for those working with weather satellites.
- Radiant Earth provide Jupyter Notebooks and training data to help you work with Earth observation data and machine learning techniques.

There are also a variety of cloud based infrastructures that can support you in connecting code to data.

- The Copernicus WEkEO Data and Information Access System (DIAS) cloud platform offers a free Jupyter Hub that you can use to develop cloud-based code to exploit many Copernicus data records, including those from the Sentinel satellite series. It also offers a scalable cloud infrastructure for more advanced data processing.
- Google Earth Engine can be used to explore a wide catalogue of free and open satellite data, particularly when the application is focussed on land applications.

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4.7.5 Summary reports

Some of the Copernicus services author annual reports summarising, for example, the state of the ocean or European climate. These reports often include excellent examples of data visualition and are worth consiering if you wish to create similar ones. IPCC Assessment and Special Reports can also offer similar inspiration.

- Copernicus Marine Service State of the Ocean report
- Copernicus Climate Change Service European state of the climate report
- IPCC reports

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4.7.6 Other data visualisation guides and resources

While not typically focussed on Earth observation, there are a number of other useful data visualisation guides out there. Below you will find a list of some useful resources that you may wish to consider when creating your own visualisations.

- WWF data visualisation guide
- Ten simple rules for better figures
- Coursera Data Visualisation courses
- GEO University

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4.8 Examples stories and visualisation for different environmental thematics

4.8.1 Air quality and wildfire visualisations

Satellite data can provide views on the impact of human activities.

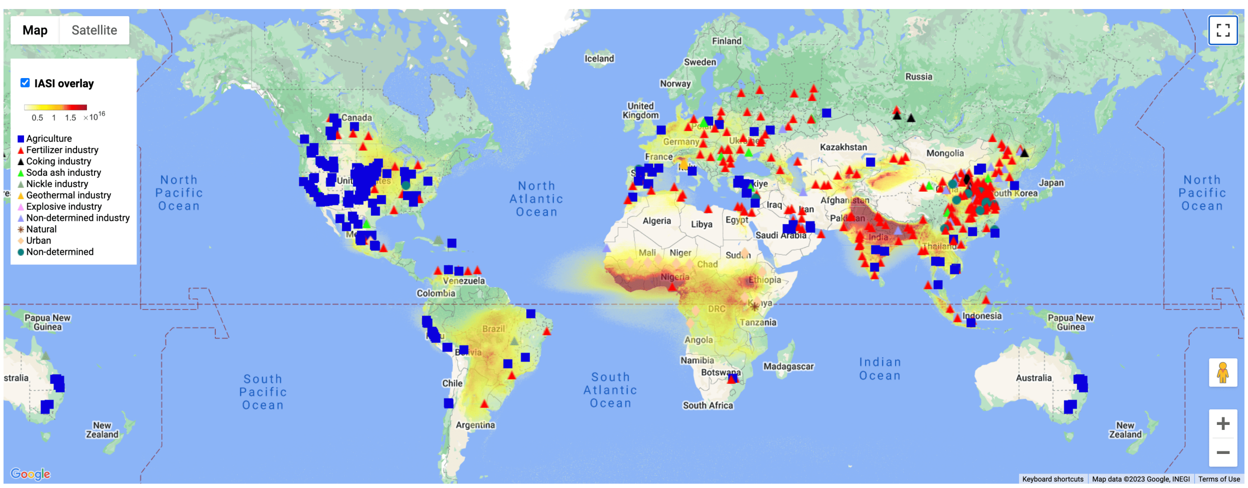

Fig. 7: *Ammonia concentration measured by IASI, overlaid on a map of likely production sites (Credit: Lieven Clarisse and Martin Van Damme).*

Satellite data can be used to show things the human eye cannot readily perceive - like concentrations of pollutants in the air.

Satellite images can provide perspective on the extent of events in the current news cycle.

Satellite data can visualise problems that are invisible to humans and occuring in remote regions.

Satellites can provide multiple perspectives on a phenomenon. This visualisation combined both visible and infrared measurements to highlight a lava flow in the context of the surrounding region.

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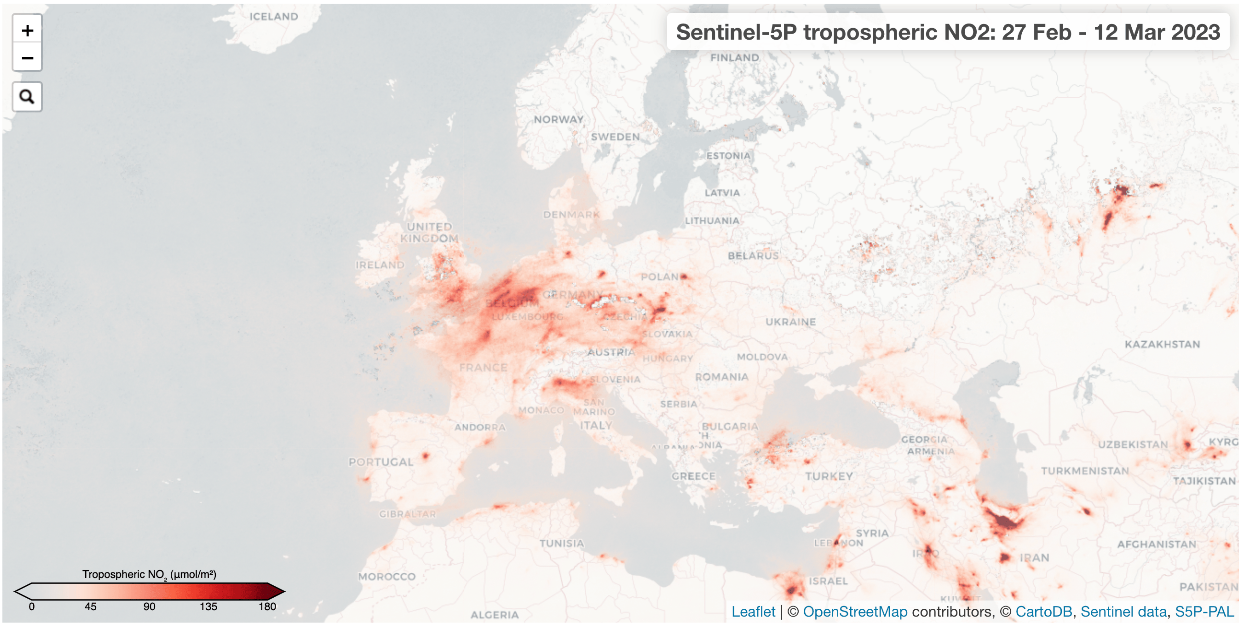

Fig. 8: *Nitrogen dioxide measure by Sentinel-5P (Credit: ESA).*

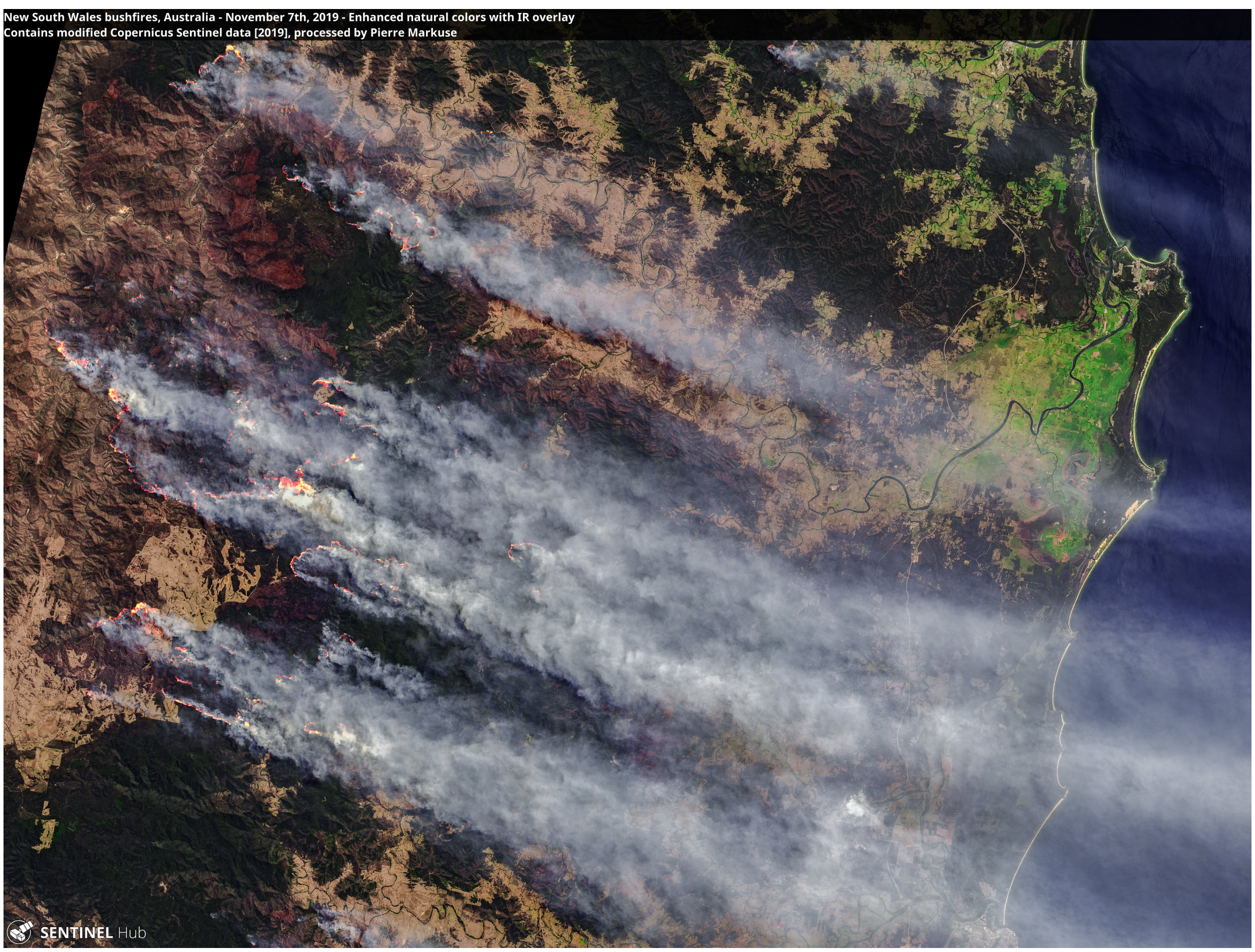

Fig. 9: *Wildfire extent captured in the visible and short wave infra-red by Sentinel-2 (Credit: Pierre Markuse).*

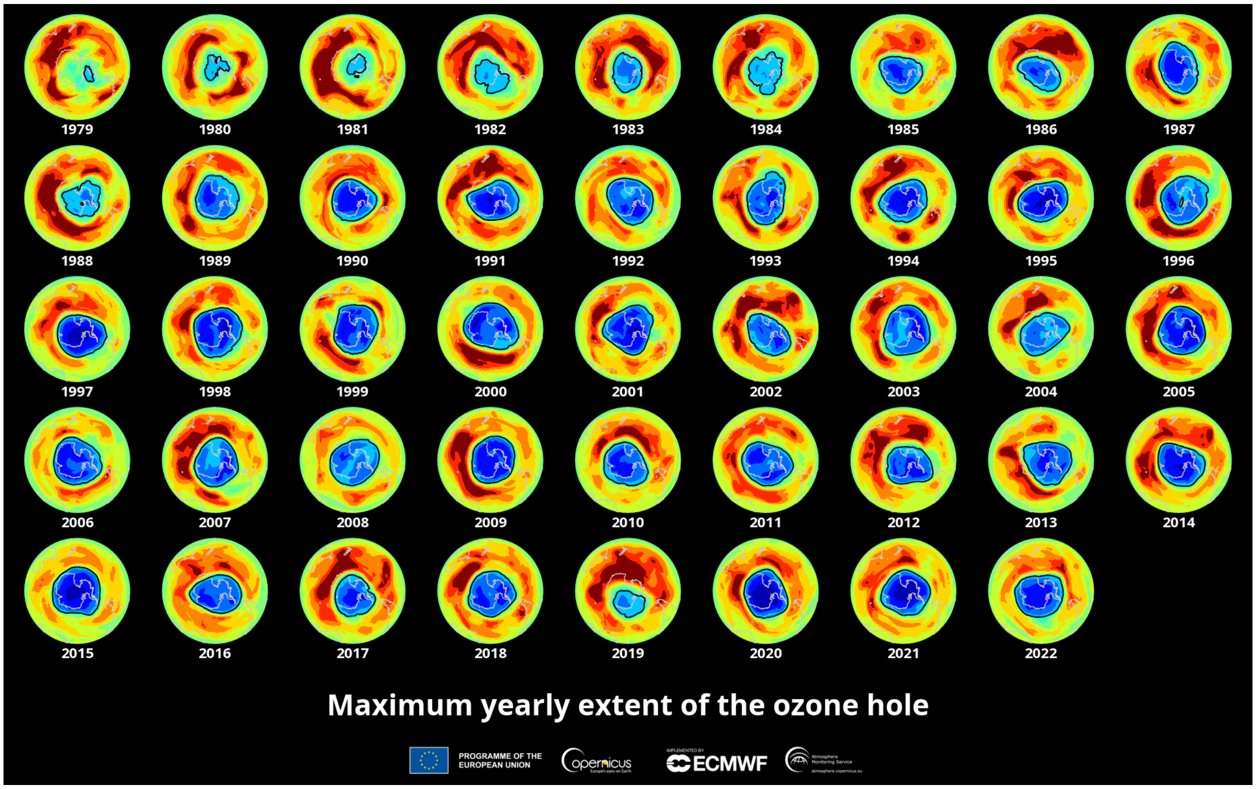

Fig. 10: *Evolution of the ozone hole (Credit: Copernicus Atmospheric Monitoring Service).*

4.8.2 Oceans and sea ice visualisations

Satellite data can reveal underlying physics, beautiful painting-like patterns, and risks to humans (such as those from some types of algal blooms).

Whilst providing information is a core aim of most EO visualisation, artistic and creative approaches can also be inspiring.

Combining EO data sources can be useful when explaining phenomena.

Visualisation platforms such as MyOcean can allow for rapid exploration and visualisation of data.

Many datasets contain variables offering different perspectives on a domain, and can be presented in different ways to provide a more complete picture of a situation.

Visible imagery from Sentinel-2 highlighted reported changes in Venice during a COVID-19 lockdown. This initial investigated evolved in to a full scientific study.

Clear labelling, and annotation can help make visualisations much more understandable. Including links to sources can help viewers recognise legitimate data sources.

More and more news sites are providing visualisations via their own dashboards. Comparing multiple data sources can help communicate the reliability of key conclusions in stories told with EO data.

EO data can be supplemented with other data sources towards a wide variety, of societally and environmentally valuable applications.

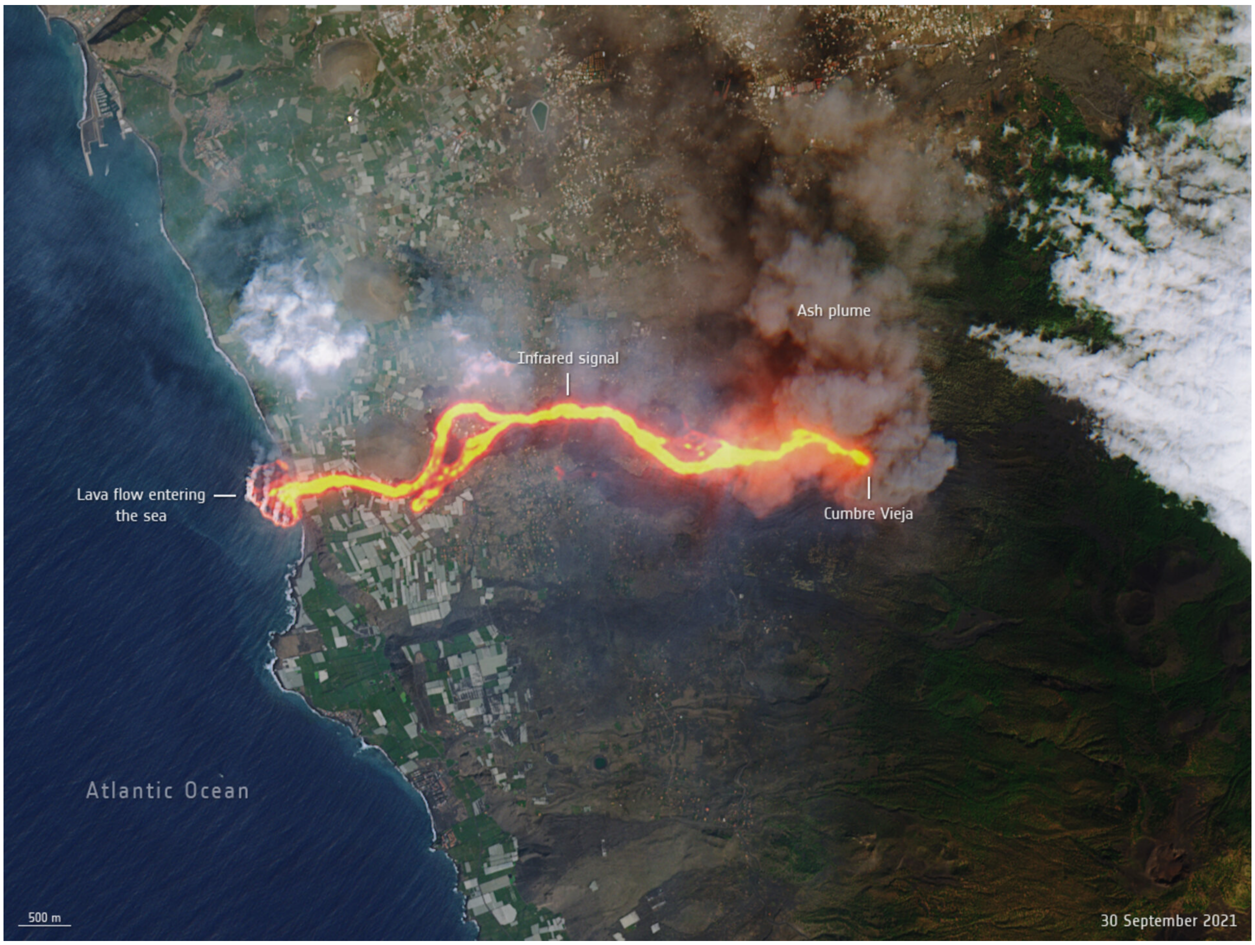

Fig. 11: *Lava flow and ash plume from the La Palma Volcano, captured by Copernicus Sentinel-2 (Credit: ESA).*

Fig. 12: *Algal blooms caught in an eddy (Credit: Aida Alvera-Azcárate and Sentinel-Hub).*

Fig. 13: *Viewing ocean colour signals with different palettes (Credit: Aida Alvera-Azcárate).*

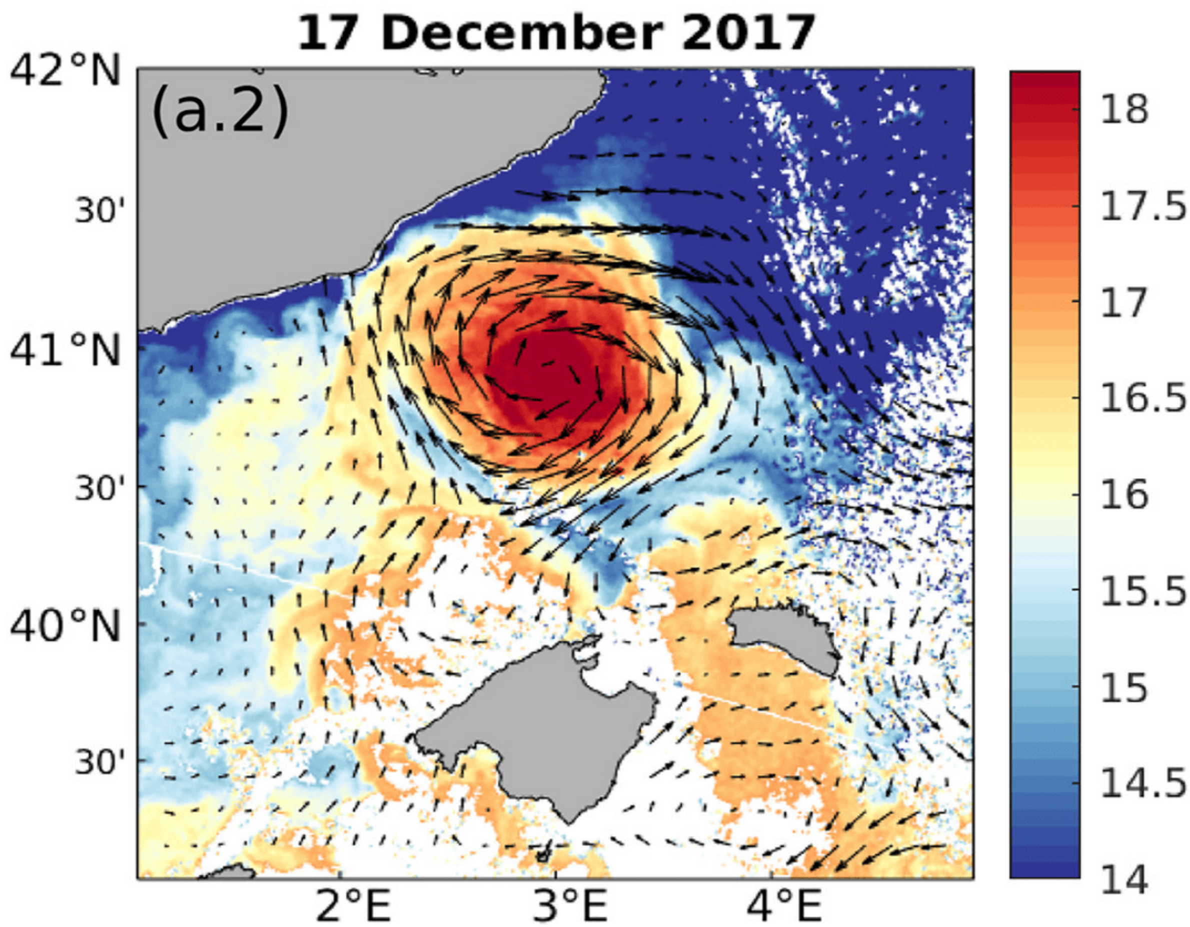

Fig. 14: *Eddy dynamics in the Balearic Sea (Credit: JGR Oceans;Wiley).*

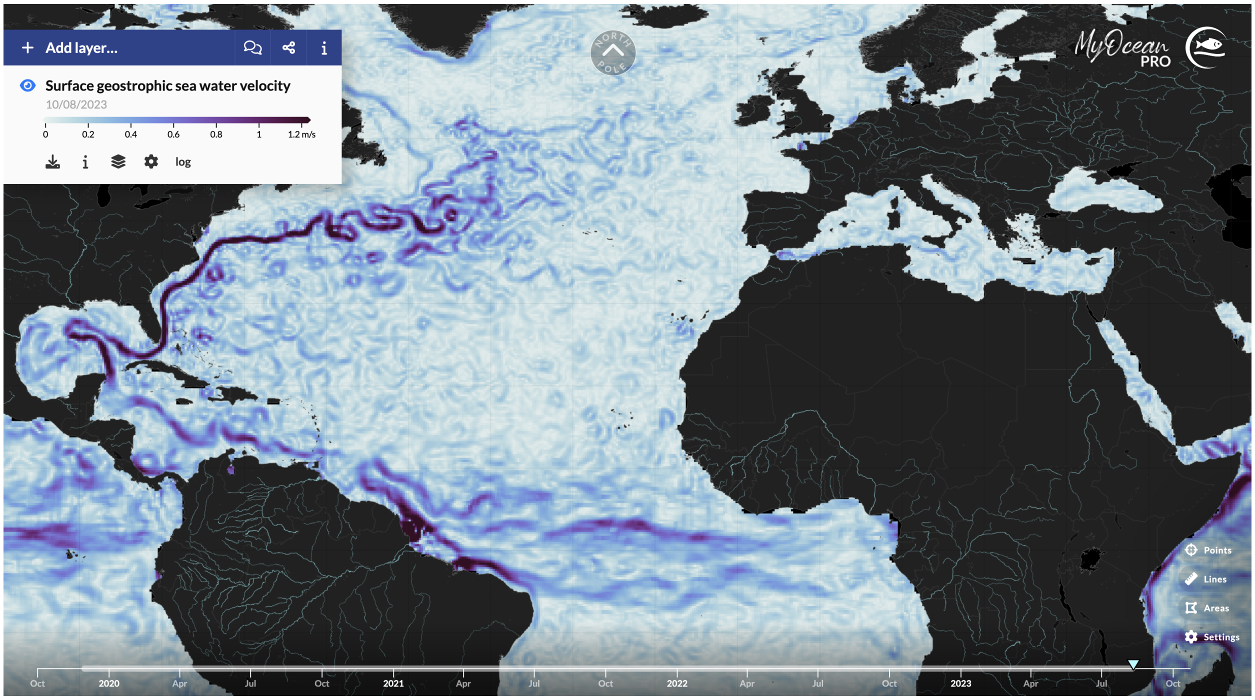

Fig. 15: *Surface geostrophic velocity product in Arctic and Antarctic sea ice coverage since 1980 (Credit: Copernicus Marine Service).*

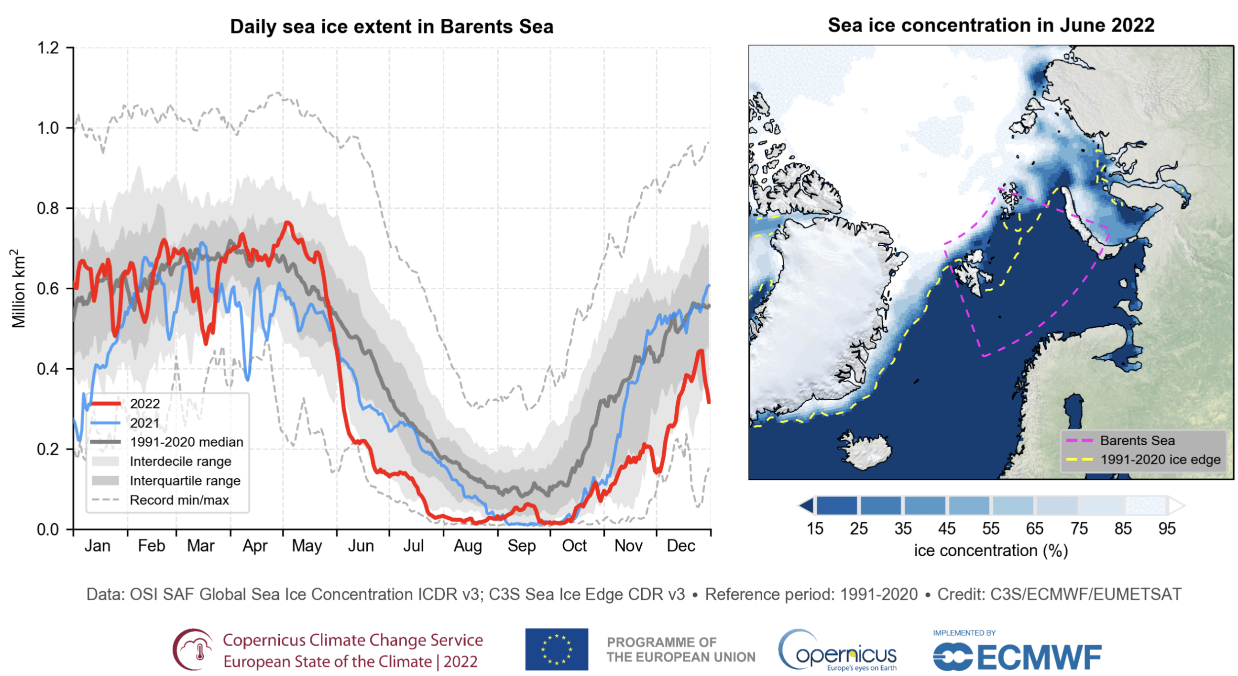

Fig. 16: *Sea ice coverage in the Barents Sea (Credit: OSI SAF and Copernicus Climate Change Service).*

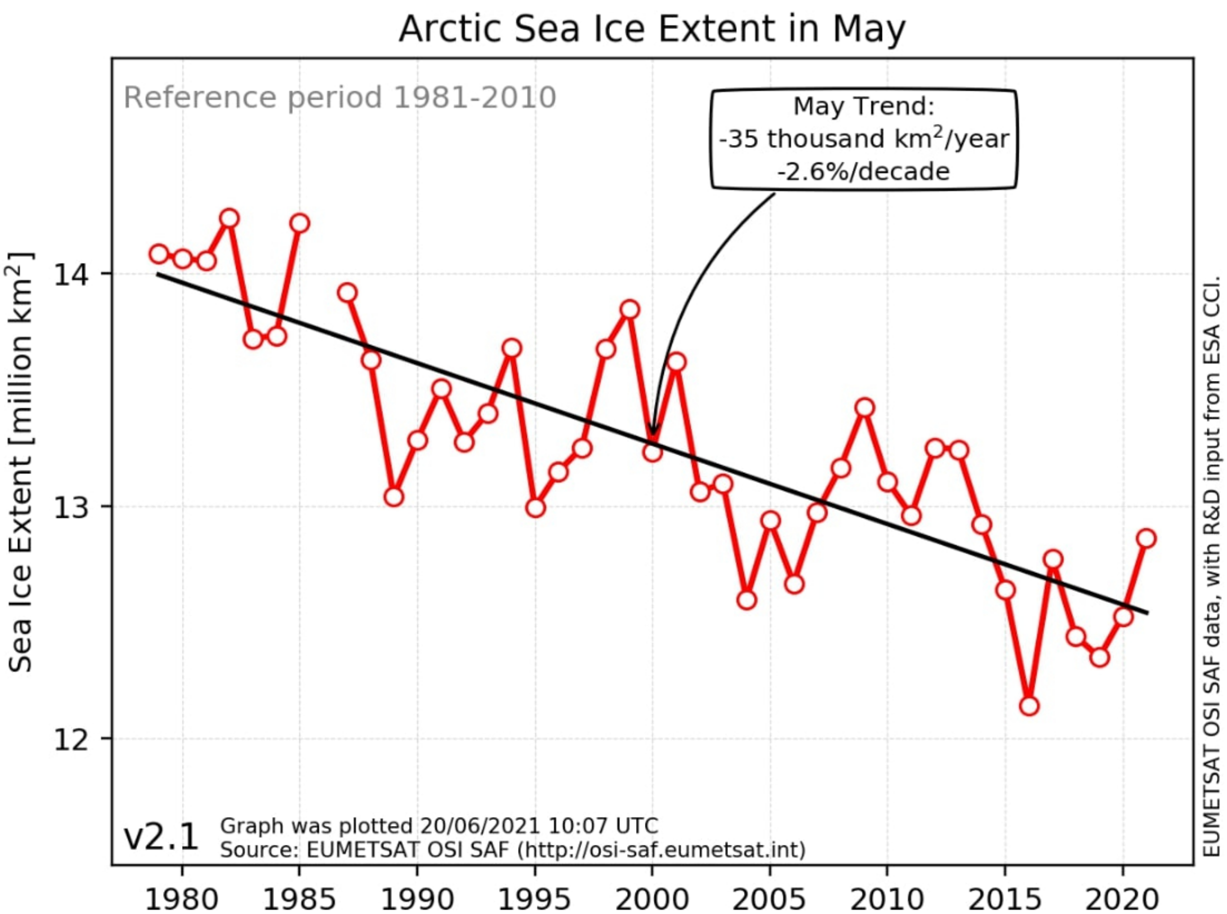

Fig. 17: *Annual change in Arctic sea ice coverage in May since 1980 (Credit: Associated Free Press and EUMETSAT OSI SAF).*

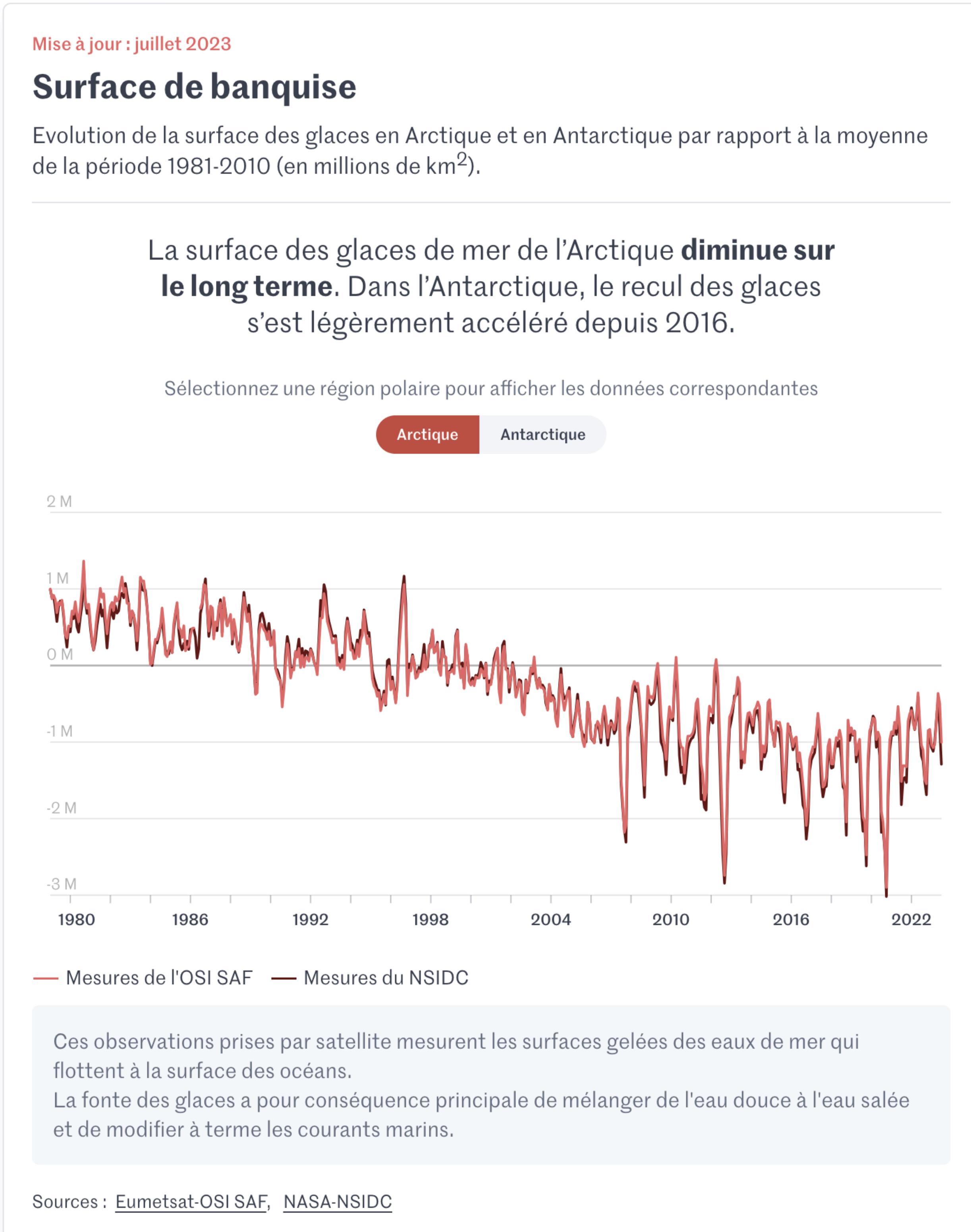

Fig. 18: *Change in Arctic and Antarctic sea ice coverage since 1980 (Credit: Le Monde and EUMETSAT OSI SAF).*

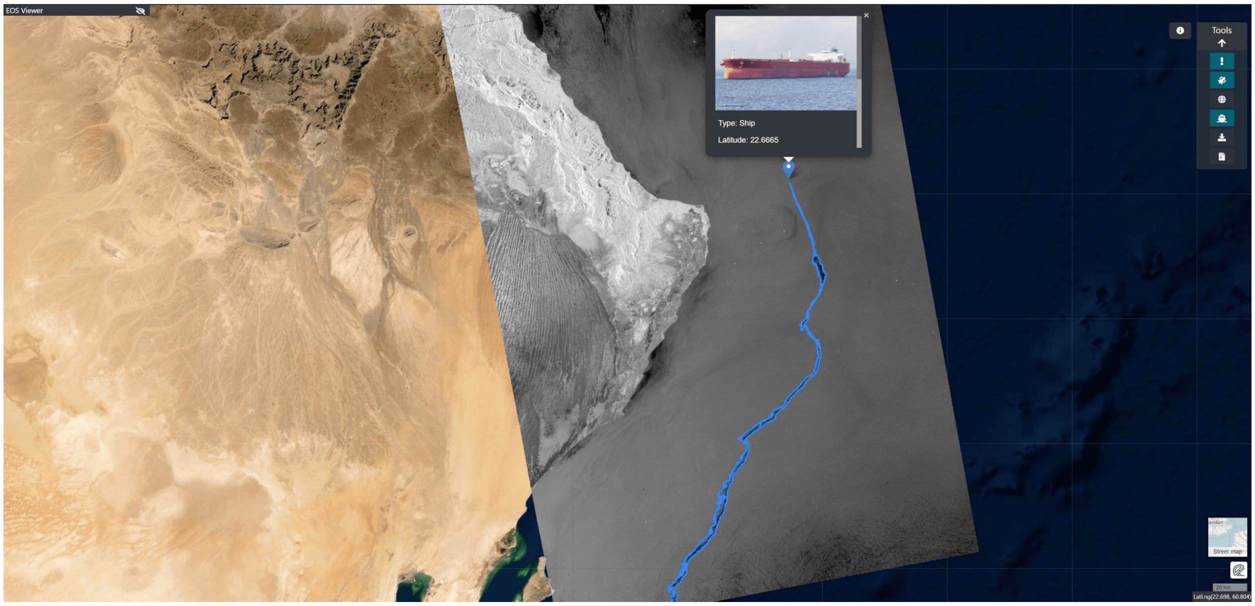

Fig. 19: *Satellite use in oil spill tracking (Credit: Orbital EOS and CMCC).*

4.8.3 Climate and weather visualisations

Even when not visualised itself, data can still inform story telling. Clear and concise statements can distill vast of amounts of data in to stories that anyone can understand.

Repeating visualisation can readily show signficant changes across a data set.

Visualisations have the potential to become memes, and can be repeated in many contexts.

Providing comparisons that people can readily understand, can greatly aid visualisation.

Clear comparisons, with use of consisistent style, labelling, and data baselines, can tell stories of change, and refute inaccurate claims.

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4.8.4 Climate extremes: heatwaves, changes in ice and drought visualisations

Animations can be used to great effect to enhance visualisations and are particularly popular in newer social media contexts that favour video formats.

Indices can simplify visualisations to give viewers a more relative understanding of a phenomena and its impacts.

Divergent colour scales can be useful for visualising trends and anomalies.

Video based formats offer an excellent way to combine static images, animations and narration to explain complex topics.

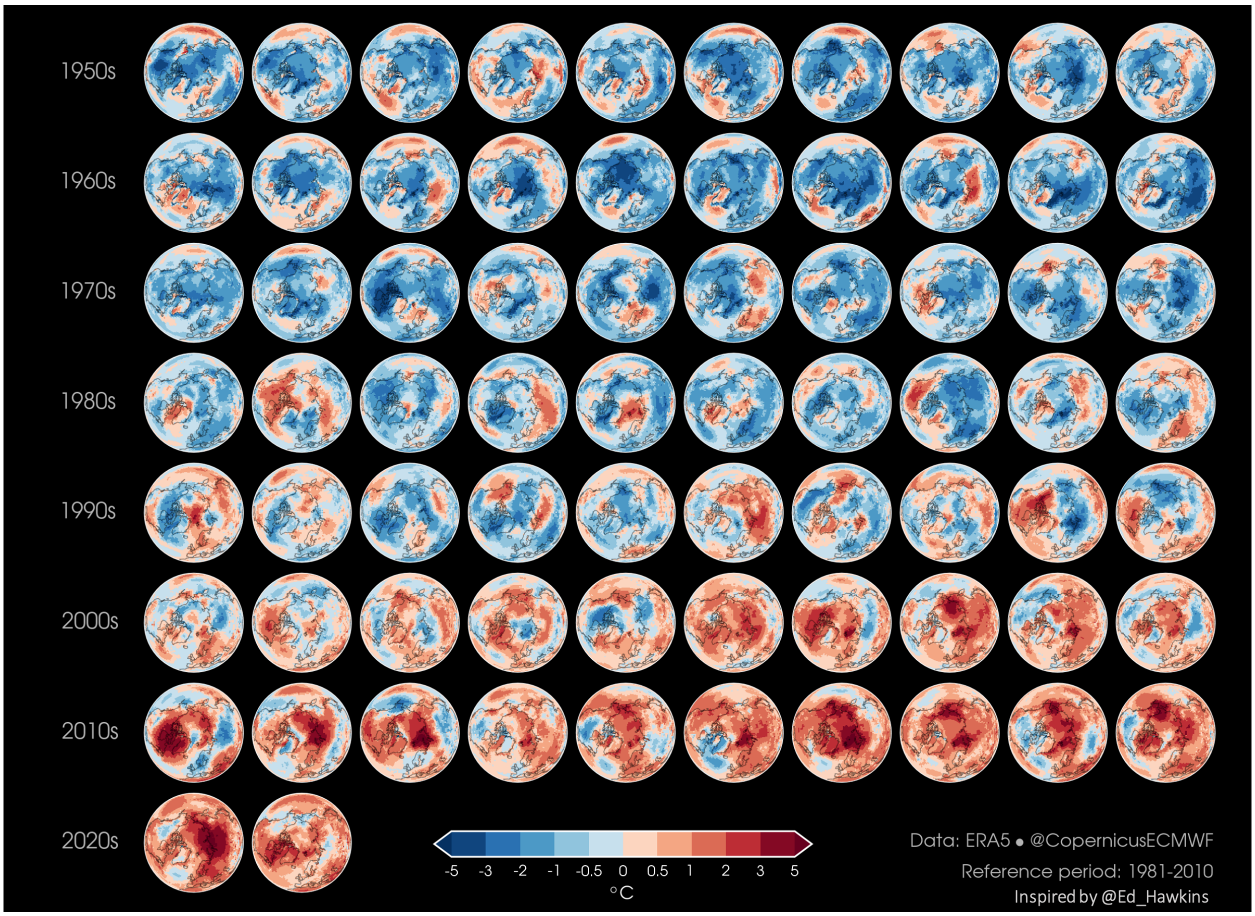

Fig. 20: *ERA5 annual mean temperature anomaly (Credit: Copernicus Climate Change Service).*

Fig. 21: *Visualising climate stripes (Credit: University of Reading).*

Fig. 22: *The Pope discussing climate stripes (Credit: Cristina Nadotti @CriNadot)*

Fig. 23: *Greta Thunberg holding "The Climate Book" (Credit: Imperial College London)*

Fig. 24: Glacial ice loss in the alps in 2022 (Credit: Copernicus Climate Change Service).

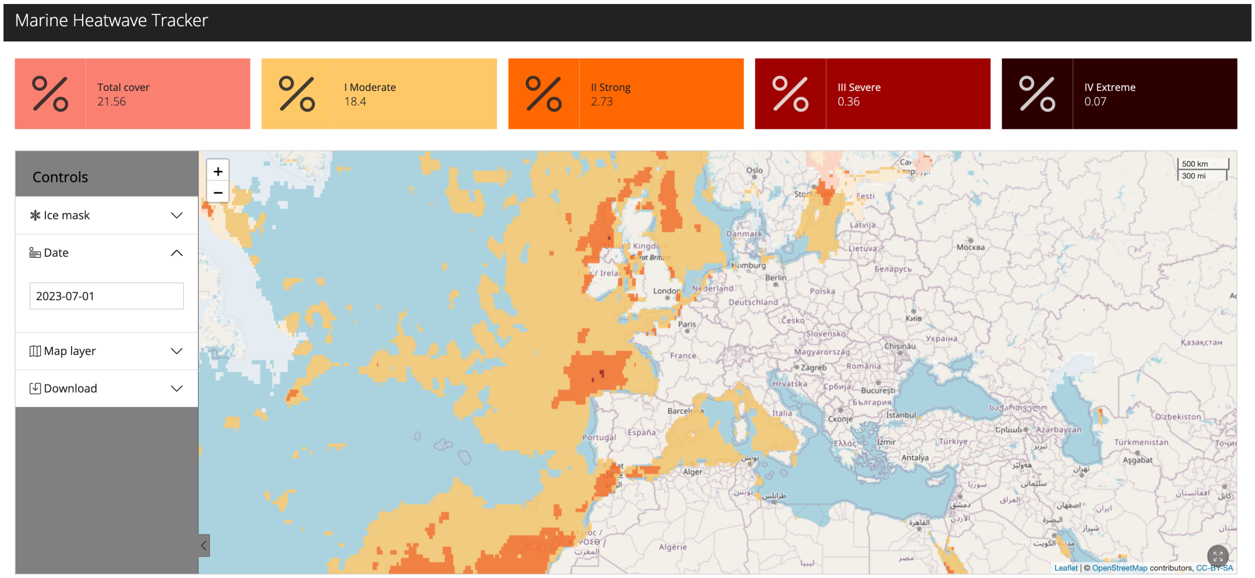

Fig. 25: *Visualising marine heat waves (Credit: marineheatwaves.org).*

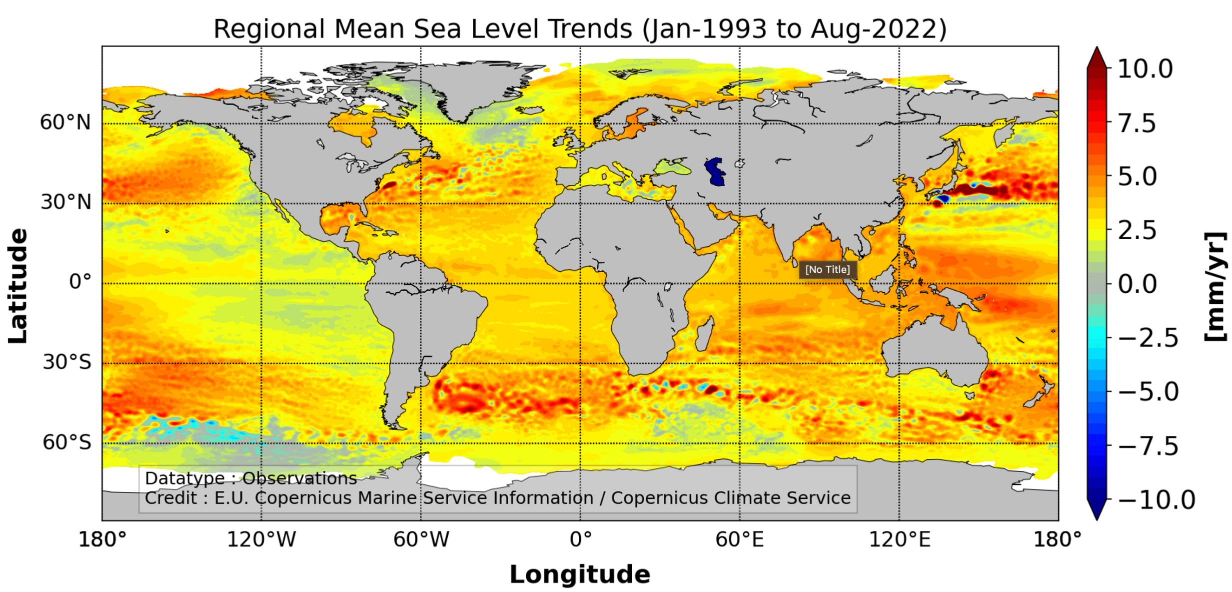

Fig. 26: *Visualising sea level trends (Credit: Copernicus Marine and Climate Change Services).*

https://youtu.be/br9N_Cqmfz0

Satellite products can provide broad perspectives on the impacts of events, such as in this example, where the impacts of floods on land are caputred further in their impacts on the coastal marine environment. These can be particular powerful to bring a sense of scale to images on the ground such as those shown in the video below.

https://youtu.be/CyctkySOLx0

Rapid and clear visualisation of core information is essential for disaster response.

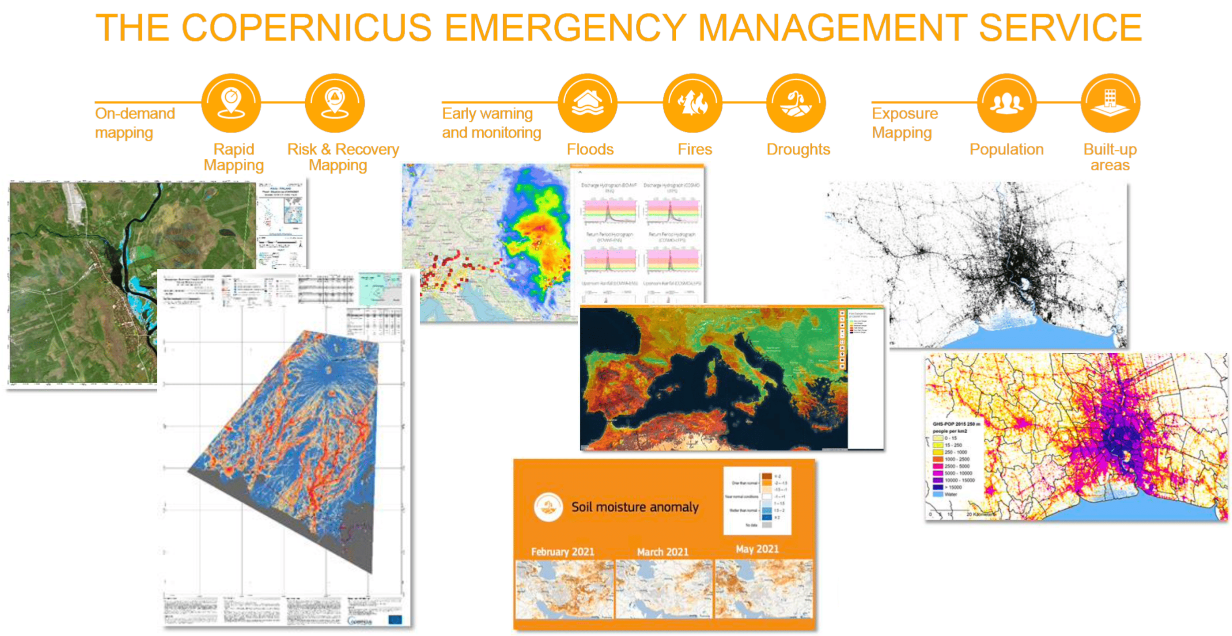

Fig. 27: *View options for the Copernicus Emergency Management Service (CEMS) (Credit: Copernicus Emergency Management Service).*

It is particularly important to provide long-term context for events being reported in the present. Growing numbers of climate quality data records can be used for this.

For further examples from news media, also see the page on *journalists perspective*.

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4.9 How can data providers make storytelling easier?

The data visualisation workshop that prompted the first draft of this guide instigated a lot of discussion about what data providers can do to make storytelling easier for others. Here we have gathered some key points related to this topic, to help data providers with the definition of future requirements:

To support storytelling, data providers can:

- Provide regular images in timely response to events e.g. Copernicus image of the day, EUMETSAT case studies.
- Make images reusable: Offer images under open licensing conditions that are clear, and allow for sharing.
- Make images editable: storytellers frequently need to alter images to suit their context. This could mean changing regional and/or temporal focus, it could also mean altering the style (font, colours etc). Data providers can facilitate this by providing platforms that allow for image editing, and/or making code for image generation open source reusable with suitable licence conditions.
- Compile annual reports of important environmental metrics e.g. European State of the Climate and Ocean State Report
- Provide fitness-for-purpose information, so that non-experts can find suitable data sets for different applications.
- Provide expert user support.
- Support their subject experts in creating an online, personal presence to participate in networking activities related to storytelling.

4.9.1 Data providers and services

Below is a non-exhaustive list of data providers alongside some of their associated services - please do suggest additions!

Table 1: Copernicus services

Provider	Services	Available data
Copernicus Marine Service (CMEMS)	My Ocean Viewer (WMS/Web API) Marine Data Store (Web API/OpenDAP/ERDDAP/FTP/WMS)	Ocean indicators and marine data from satellite, numerical model and *in situ* sources at operational, reprocessed and climate scales.
Copernicus Atmospheric Monitoring Service (CAMS)	Daily charts Atmospheric Data Store (Web GUI/API)	Atmopsheric charts and data from from satellites and numerical models at near operational and reprocessed scales.
Copernicus Climate Change Service (C3S)	Climate Data Store (Web GUI/API)	Climate indicators, data and reports for the atmosphere, ocean and cryosphere.
Copernicus Land Service (CLMS)	Land Service Portal (Web GUI) Product access (Web API/FTP)	Land products.
Copernicus Emergency Management Service (CEMS)	Rapid and Risk mapping services portal (Web GUI)	Situational map information on current emergencies from various sensors and data providers.

Table 2: Satellite agencies

Provider	Services	Available data
EUMETSAT	EUMETView (WMS/WFS/WCS) EUMETSAT Data Store (Web GUI/API) EUMETSAT Data Centre (Web order; authentication required)	Weather, climate, atmospheric and marine satellite products at operational, reprocessed and climate scales.
European Space Agency (ESA)	Sentinel SciHub (Web GUI/API) EO Gateway Ocean Virtual Laboratory	Atmospheric and marine satellite products from research and operational missions.

Table 3: Numerical weather prediction providers

Provider	Services	Available data
European Centre for Medium Range Weather Forecasting (ECMWF)	Data archive (API) Chart viewer and browser	Reanalysis and forecast charts and data sets. Many products available through the Copernicus Climate Data Store.

Table 4: EUMETSAT Satellite Application Facilities (SAFs)

Provider	Available services and data
Ocean and Sea Ice SAF (OSI SAF)	Sea surface temperature, wind and sea ice product access, publications and visualisations.
Atmospheric Composition SAF (AC SAF)	Atmospheric composition product access
Climate Monitoring SAF (CM SAF)	Climate product access, and latest images
Land Surface Analysis SAF (LSA SAF)	Land product access and product gallery
Hydrology and Water Management SAF (H SAF)	Hydrological product access

Table 5: Cloud providers

Provider	Services	Available data
WEkEO	Data viewer and downloader	EUMETSAT, ESA and Copernicus service data across multiple thematics

Table 6: Commercial services

Provider	Services	Available data
Sentinel Hub	EO Browser API data access	Various products from the Copernicus Sentinel Programme and Copernicus Services, as well as products from Landsat, ENVISAT, MODIS and commercial providers.

4.10 Visualisation Checklist - 10 points to consider

Key points to think about when storytelling with Earth observation data

1. Have you made sure that your image/animation is **simple and easy to understand**. If you can, test it with others before releasing it.
2. Does your image have a simple key, scale bar, and where relevant a background map, so that people understand the context and everything is clear in the image or animation?
3. Try to use a colour scheme that is clear and **appropriate for the data shown**.
4. Have you annotated the main features that you want to show e.g., wildfires? Don't assume that it will be obvious to everyone.
5. If you have labels on your image, try to **keep text to a minimum** and **avoid jargon** or specialised technical terms.
6. Can you include additional supporting information, where possible, to back up your image/animation?
7. If possible can you provide links, for instance, links to scenes in online Earth observation data viewers, so that others can recreate your image?
8. Have you made sure that your image/animation will **work with all mobile formats** for social media channels?
9. If it is a single image, would it be better to animate a series of images to make the focus more easy to see and understand?
10. Where possible, try to blend different types of Earth observation data, e.g., infrared or SAR data, as well as true colour imagery if it will help to highlight the focus of your image or animation.

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4.11 Workshop presentations

Recordings of the Copernicus Earth Observation Data Visualisation workshop which first prompted the creation of this guide, are available on the EUMETSAT YouTube channel

Below you can find the associated slides of the presentations given during the workhop, arranged by thematic week and in PDF format.

- Week 1: Introduction to EO Data Visualisation
- Week 2: Air Quality and Wildfires
- Week 3: Oceans and Sea Ice
- Week 4: Climate and Weather
- Week 5: Climate Extremes: heatwaves, changes in ice and drought
- Week 6: Being Practical: How to access and process Copernicus and EUMETSAT data

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