JNCC

Simple ARD Service
Information for Users

Version 1.0, September 2020

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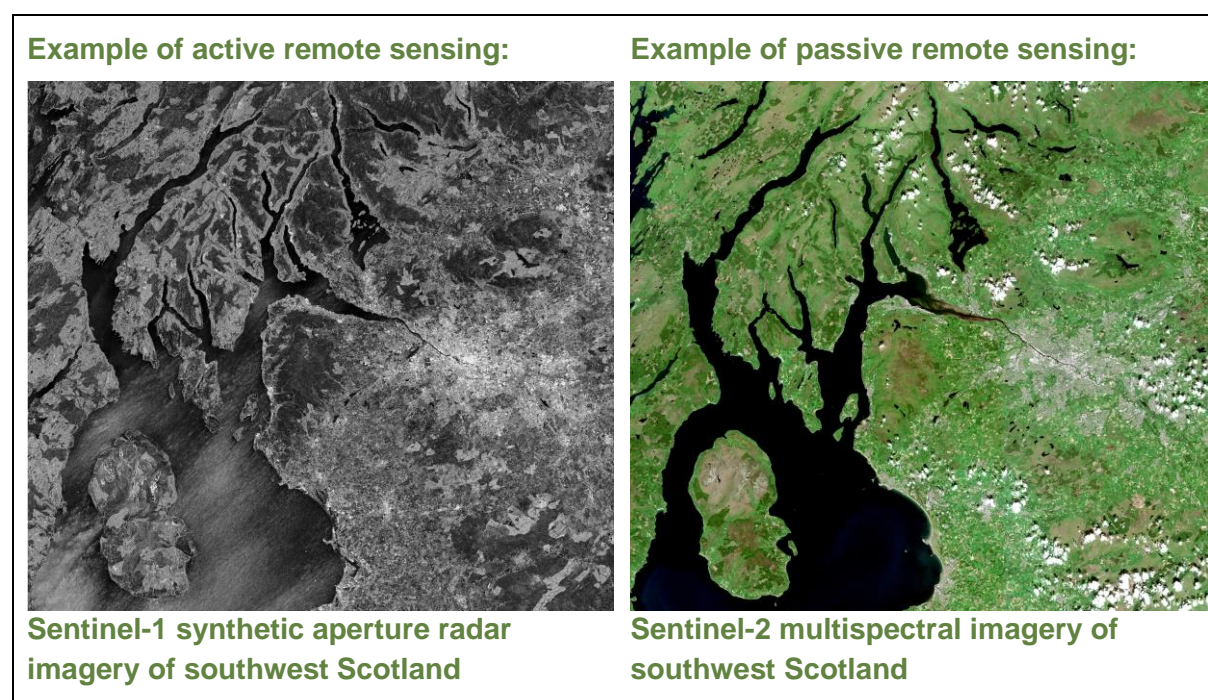
About the Simple ARD Service
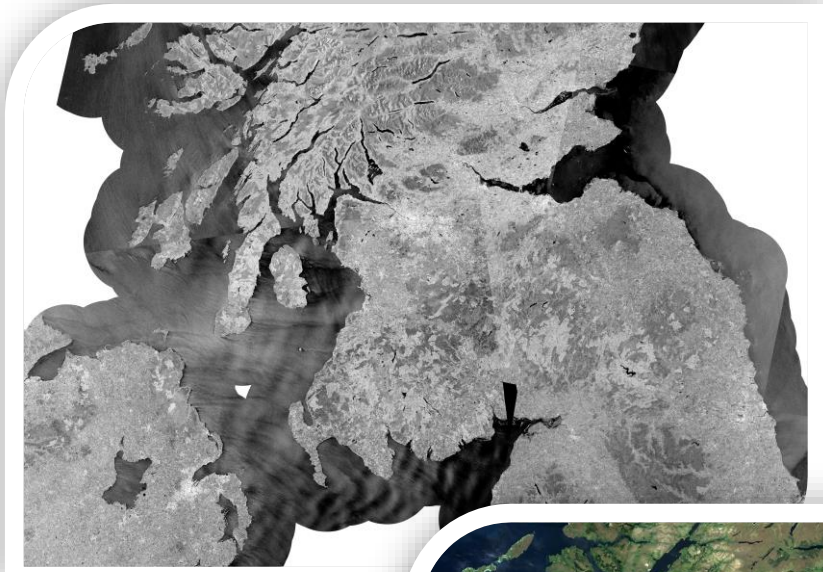
The Simple ARD Service (SAS) was set up by JNCC in 2020 with support from the Scottish Government and Northern Ireland Environment Agency. It aims to facilitate use of satellite data for public sector environmental applications by generating and providing access to Sentinel-1 (S1) and Sentinel-2 (S2) analysis-ready data (ARD) for Scotland and Northern Ireland. Processed data are stored and made publicly accessible via the Centre for Environmental Data Analysis **(CEDA) Archive**.

The Simple ARD Service complements Defra's **Earth Observation Data Service** (EODS) by providing access to ARD beyond England. ARD produced by the EODS is also publicly available via the CEDA Archive. Data and metadata from both services are produced by the same methods to the same standards, enabling UK-wide analytical applications.

This document provides information about S1 and S2 ARD and guidance on how to access data via CEDA.

Earth Observation

Earth observation (EO) is the gathering of information about the Earth's biological, physical and chemical systems via active or passive remote sensing technologies. Active sensors emit a signal, such as a radar, sonar or laser pulse, and record its echo as it bounces back from the Earth's surface. Passive sensors capture only natural energy that is emitted or reflected from the Earth's surface, such as reflected sunlight. Examples are shown in Figure 1.

Example of active remote sensing:

Example of passive remote sensing:

Sentinel-1 synthetic aperture radar imagery of southwest Scotland

Sentinel-2 multispectral imagery of southwest Scotland

Figure 1: Examples of active and passive remote sensing

Both active and passive remote sensing generate spatial data, such as the raster imagery shown above. This can be visualised and interpreted alongside other spatial and non-spatial

data, for example to create habitat maps, monitor coastal erosion or predict wildfire risk. EO data has numerous environmental applications in fields including forestry, crop health, flood risk, coastal management, water quality, biodiversity conservation and natural capital assessment.

The quality and quantity of Earth observation data is rapidly increasing, providing unprecedented opportunities to improve environmental decision-making and meet operational evidence needs. In particular, the Sentinel satellites in the European Space Agency's (ESA) Copernicus programme provide openly accessible high resolution data every few days.

Before satellite imagery can be used, it needs to be cleaned to correct distortions caused by the Earth's atmosphere and topography. The data processing methods used by the Simple ARD Service are outlined below.

Sentinel-1 and Sentinel-2 Analysis-Ready Data

Satellite missions and data processing methods

The **Sentinel-1 mission** collects C-band synthetic aperture radar (SAR) data. This is an example of active remote sensing, in which the satellite emits a radar pulse and records the echo reflected from the earth's surface. Twin satellites Sentinel-1A and 1B operate day and night, unaffected by cloud cover.

S1 data is processed by the Simple ARD Service using ESA's Sentinel Application Platform (SNAP) toolbox (**https://step.esa.int/main/toolboxes/sentinel-1-toolbox/**) to produce a topographically corrected, radiometrically normalised Gamma-0 backscatter product in decibels.

Raw S1 data can be processed to produce different products, but a backscatter product was deemed most useful for a number of terrestrial environmental applications. Radar backscatter is influenced by terrain structure and surface roughness, and can therefore provide information on environmental conditions such as forest structure, flood extent and soil moisture.

The **Sentinel-2 mission** is a constellation of two satellites collecting multispectral imagery suitable for land monitoring applications. This is an example of passive remote sensing, in which the satellite captures the sunlight reflected from the earth's surface.

S2 data is processed by the Simple ARD Service using Aberystwyth University's Atmospheric and Radiometric Correction of Satellite Imagery (ARCSI, **www.arcsi.remotesensing.info/**) software to produce a topographically corrected surface reflectance product with cloud and topographic shadow masks that can be applied to the imagery. Further details of the S2 processing methods are available in **this report**. Surface reflectance shows which wavelengths of light are most strongly reflected and which are absorbed, providing insight into environmental conditions such as crop health and habitat condition.

Further information on the S1 and S2 missions and data can be found on the ESA website:

|			
S1:	**Mission Information**	**User Guide**	**Technical Guide**
S2:	**Mission Information**	**User Guide**	**Technical Guide**

Both S1 and S2 ARD processing for the Simple ARD Service is carried out on **JASMIN**, a globally unique data analysis facility provided by CEDA.

ARD format and file names

Sentinel-1 imagery is supplied as sections of a single orbit known as 'scenes', with a footprint of approximately 250 km x 170 km and a file size of around 4 GB. Sentinel-2 imagery is provided as 100 km x 100 km tiles from a fixed grid known as 'granules', with a file size of around 1.2 to 1.8 GB. Examples of a S1 scene and S2 granule are shown in Figure 2.

Scenes or granules which cover part of Scotland and Northern Ireland in the same file are processed twice to produce separate outputs in British National Grid and Irish National Grid reference systems.
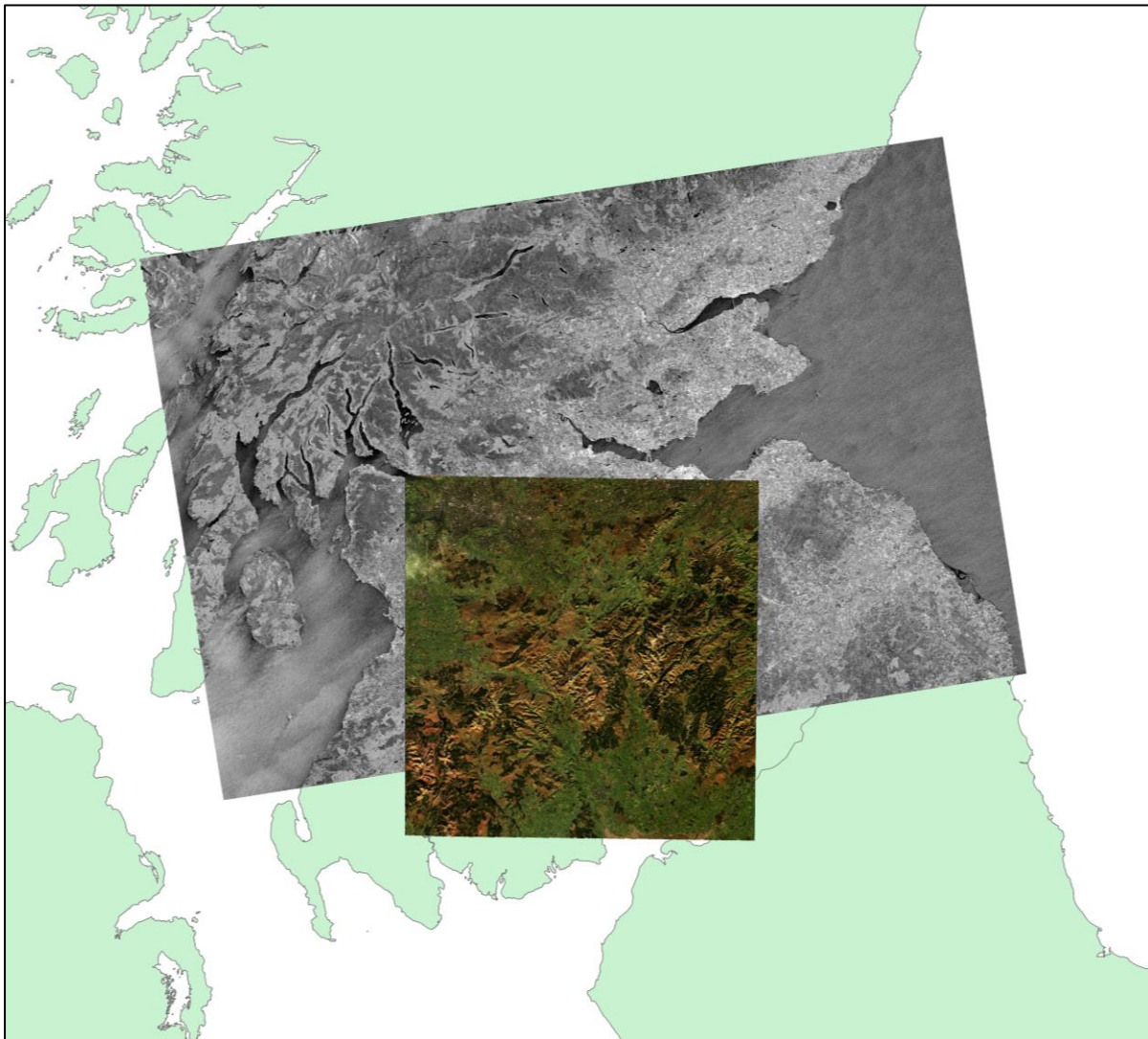
Figure 2: Example of a single Sentinel-1 scene and Sentinel-2 granule over southern Scotland

S1 ARD is a two band raster at 10 m resolution. S1 is a dual polarisation SAR system, it can transmit in either horizontal (H) or vertical (V) polarisation and receive in both H and V polarisations. Band 1 contains VV values, i.e. the signal was transmitted and received in

vertical polarisation. Band 2 contains VH values, i.e. the signal was transmitted in vertical and received in horizontal polarisation.

S2 ARD is a ten band raster at 10 m resolution. S2 sensors collect imagery with thirteen spectral bands, but the three 60 m resolution bands collect information within the atmosphere and are not designed for use in surface reflectance product, so they have been removed from the ARD products. The wavelengths and spatial resolution of the ten S2 ARD bands are shown in Table 1.

Table 1: Sentinel-2 band numbers, wavelengths and spatial resolution in original data and corresponding band numbers in analysis ready data

Band number and name in original data	Sentinel 2A Central wavelength (nm)	Sentinel 2B Central wavelength (nm)	Spatial resolution (m)	Band number in ARD
Band 1 – Coastal aerosol	442.7	442.2	60	
Band 2 – Blue	492.4	492.1	10	**1**
Band 3 – Green	559.8	559.0	10	**2**
Band 4 – Red	664.6	664.9	10	**3**
Band 5 – Vegetation red edge	704.1	703.8	20	**4**
Band 6 – Vegetation red edge	740.5	739.1	20	**5**
Band 7 – Vegetation red edge	782.8	779.7	20	**6**
Band 8 – NIR	832.8	832.9	10	**7**
Band 8A – Narrow NIR	864.7	864.0	20	**8**
Band 9 – Water vapour	945.1	943.2	60	
Band 10 – SWIR – Cirrus	1373.5	1376.9	60	
Band 11 – SWIR	1613.7	1610.4	20	**9**
Band 12 – SWIR	2202.4	2185.7	20	**10**

The filenames for S1 and S2 ARD have been standardised to provide information about the data; these filename conventions are shown in Table 2 and Table 3.

Table 2: Filename convention for Sentinel-1 analysis-ready data

Sensor name (S1A or S1B)	Date of capture (YYYYMMDD)	Relative orbit	Orbit ascending or descending	Start time (hhmmss)	Stop time (hhmmss)	Dual polarisation VV and VH V = vertical H = horizontal	Radiometric calibration (Gamma-0)	Elevation data used in processing	CRS for terrain corrected outputs (TM65 for NI, OSGB for Scotland)	Radiometric normalisation method	Speckle reduction (refined Lee)	GeoTiff format
S1B	**20200215**	**132**	**asc**	**175013**	**175038**	**VVVH**	**G0**	**GB**	**OSGB**	**RCTK**	**SpkRL**	**.tif**

Table 3: Filename convention for Sentinel-2 analysis-ready data

Sensor name (S2A/B)	Date of capture (YYYYMMDD)	Latitude and longitude	Tile number	Orbit number	Original projection	CRS of outputs (TM65 for NI, OSGB for Scotland)	Valid pixel mask	Band sharpened	Radiance	Surface reflectance	Topographically corrected reflectance	GeoTiff format
S2B	**20200220**	**lat55lon813**	**T29UNB**	**ORB123**	**utm29n**	**osgb**	**vmsk**	**sharp**	**rad**	**srefdem**	**stdsref**	**.tif**

You may come across Sentinel-2 filenames with "SPLIT1" after the tile number, e.g. S2A_20190630_lat55lon661_T29UPASPLIT1_ORB123_utm29n_TM65. This indicates that the imagery for that tile on that date is provided as two separate datasets, i.e. it has been 'split' in two. Split granules occur at the start / end of datastrips, which are portions of imagery downlinked by laser to a ground station. They can occur on any orbit in any part of the swath. Both datasets will be needed to provide full coverage of the tile (Figure 3).

Figure 3: Example of a Sentinel-2 split granule over southern Scotland

Temporal and spatial coverage of SAS data catalogue

The Simple ARD Service provides S1 and S2 ARD for Scotland and Northern Ireland. The spatial coverage of S1 consists of seven ascending orbits and five descending orbits (**Appendix 1**). S2 spatial coverage consists of five orbits producing ten granules over Northern Ireland and 41 granules over Scotland (**Appendix 2**).

The SAS data catalogue covers the period from 1st February 2019 to the present. It is maintained on a rolling basis, with new data being processed within 7-14 days of acquisition. S2 imagery with over 95% cloud cover is not processed.

Accessing Data

CEDA offers several methods of accessing data in the CEDA Archive. Internet browser-based methods offer a quick, user-friendly way to search the catalogue and identify suitable datasets. Programmatic data access methods are more suitable for analytical users wishing to integrate data access into scripted or command line workflows. Direct access via the JASMIN environment is the most efficient route for large volume data processing. This section outlines available data access methods, with links to more detailed information on CEDA's help pages.

CEDA account

Data from the Simple ARD Service is openly available to non-registered users, so you do not need a CEDA account to access S1 and S2 ARD via the CEDA Archive website. However, you will need a CEDA account if you want to access S1 and S2 ARD via the CEDA FTP server, or if you wish to access other datasets which are only available to registered users.

CEDA user accounts are quick and easy to set up and freely available to all users. If you wish to set up an account, you can do so here:
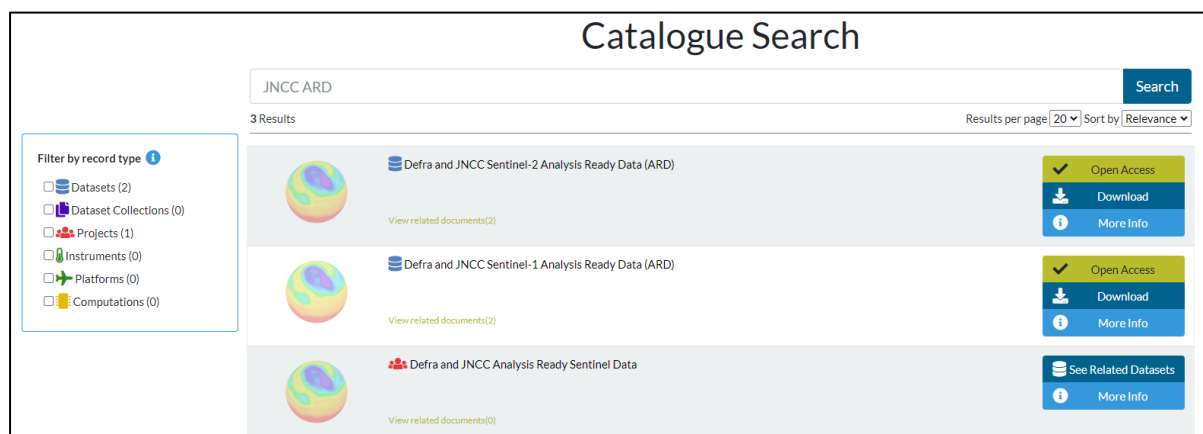
https://services.ceda.ac.uk/cedasite/register/info/

Browser-based Data Access

CEDA Data Catalogue

You can access the CEDA Data Catalogue here:

http://catalogue.ceda.ac.uk

The CEDA Data Catalogue enables users to carry out a free-text search via a simple interface to find datasets in the CEDA Archive that match their search terms (Figure 4). Returns include links to the datasets and further information. You can use the CEDA Catalogue search to find dataset-level metadata for Sentinel-1 and Sentinel-2 ARD (Figure 5).

Figure 4: Results of a CEDA Data Catalogue search for the terms "JNCC" and "ARD"

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Figure 5: Sentinel-1 ARD dataset metadata accessed through the CEDA Data Catalogue

CEDA Data Browser (Index Pages)

The CEDA Data Browser enables users to see a list of data for a particular date and download datasets of interest. You can access Simple ARD Service datasets via the CEDA Data Browser index pages here:

http://data.ceda.ac.uk/neodc/sentinel_ard/data

The datasets are archived by sensor / year / month / day. So for example, if you wish to find Sentinel-1 ARD captured on the 1st April 2019, you would click on the relevant folders in turn (Figure 6).

You can click the copy button at any point to copy the directory path to that folder.

1. Select sensor

archive / neodc / sentinel_ard / data

2 dirs 0 files	Description
📁 sentinel_1	
📁 sentinel_2	

2. Select year

archive / neodc / sentinel_ard / data / sentinel_1

3 dirs 1 files	Description
📁 2018	
📁 2019	
📁 2020	

3. Select month

archive / neodc / sentinel_ard / data / sentinel_1 / 2019

12 dirs 0 files	Description
📁 01	
📁 02	
📁 03	
📁 04	
📁 05	
📁 06	

4. Select day

archive / neodc / sentinel_ard / data / sentinel_1 / 2019 / 04

🗄 Defra and JNCC Sentinel-1 Analysis Ready Data ℹ

30 dirs 0 files	Description
📁 01	
📁 02	
📁 03	
📁 04	
📁 05	
📁 06	
📁 07	
📁 08	
📁 09	

Figure 6: Navigating through the CEDA Archive index pages

Selecting a day opens a folder containing all the available datasets acquired on that date. Each Sentinel-1 ARD dataset consists of two files: the data file (.tif) and the metadata (.xml). The datasets are listed in alphabetical order by file name, and the size of each file is shown next to the file name (Figure 7).

archive / neodc / sentinel_ard / data / sentinel_1 / 2019 / 04 / 01

0 dirs 34 files	Description	Size	Actions
📄 S1A_20190401_103_asc_180536_180605_VVVH_G0_GB_OSGB_RTCK_SpkRL.tif		4.3 GB	⬇
📄 S1A_20190401_103_asc_180536_180605_VVVH_G0_GB_OSGB_RTCK_SpkRL_meta.xml		16.4 KB	⬇
📄 S1A_20190401_103_asc_180605_180630_VVVH_G0_GB_OSGB_RTCK_SpkRL.tif		3.9 GB	⬇
📄 S1A_20190401_103_asc_180605_180630_VVVH_G0_GB_OSGB_RTCK_SpkRL_meta.xml		16.4 KB	⬇
📄 S1A_20190401_103_asc_180630_180655_VVVH_G0_GB_OSGB_RTCK_SpkRL.tif		3.8 GB	⬇
📄 S1A_20190401_103_asc_180630_180655_VVVH_G0_GB_OSGB_RTCK_SpkRL_meta.xml		16.4 KB	⬇

Figure 7: Index page for Sentinel-1 data acquired on 1st April 2019 showing three datasets each consisting of two files

Each Sentinel-2 ARD dataset consists of either six or seven files (Figure 8). Every dataset consist of the imagery data file, metadata, cloud mask, saturated pixel mask, topographic shadow mask, valid pixel mask, and some datasets also include a thumbnail image jpeg file.

Figure 8: Index page for Sentinel-2 data acquired on 1st April 2020 showing one dataset consisting of seven files

You can view metadata or download data by clicking on the file name or clicking the download button under 'Actions'.

Satellite Data Finder

The CEDA Satellite Data Finder is an interactive map with filters which lets you search for data by area of interest and date range (Figure 9). You can access the Satellite Data Finder here:
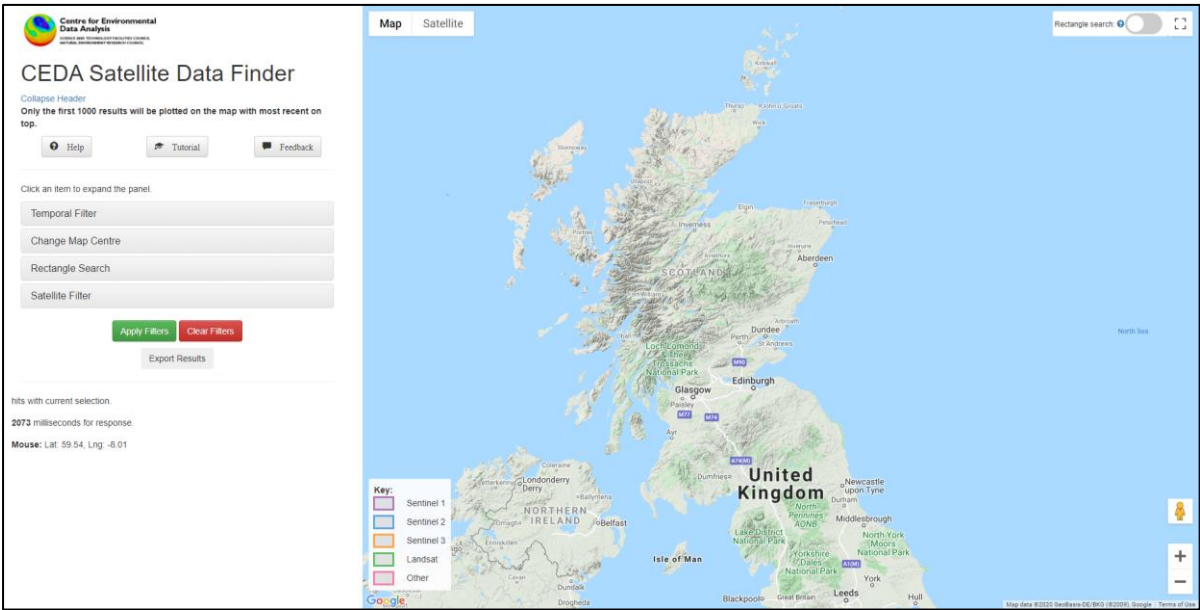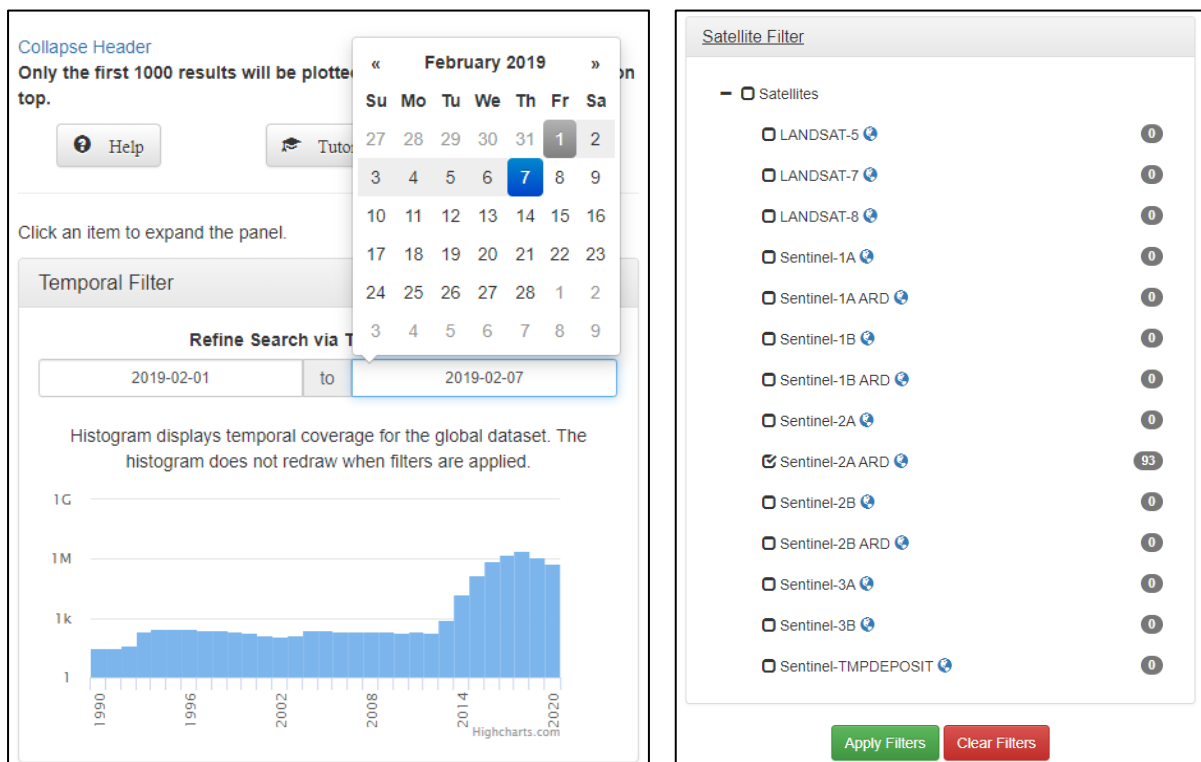
http://geo-search.ceda.ac.uk/

Figure 9: CEDA Satellite Data Finder

To search for data, apply the temporal and satellite filters on the left side of the screen (Figure 10). Enter a start and end date in the temporal filter in YYYY-MM-DD format or by using the interactive calendar. Select one or more satellite from the satellite filter using the tick boxes.

Figure 10: Temporal and satellite filters on CEDA Satellite Data Finder

Click the Apply Filters [Apply Filters] button to activate the selected filters and view results on the interactive map.

Click the Clear Filters [Clear Filters] button to clear the results and start again.

Click the Export Results [Export Results] button to obtain a list of all files returned by the search parameters in raw JSON, file paths or download URLs.

The Rectangle Search and Change Map Centre functions (Figure 11) are not operational at the time of writing. In future, these functions will enable users to search for data in an area of interest by drawing a bounding box on the interactive map, and to centre the interactive map on a location by entering a place name in the search box.

Figure 11: Rectangle search and change map location functionality (not currently operational)

In the meantime, you can carry out a geographic search by using mouse controls to pan and zoom the map to an area of interest. The coverage of available data is shown on the map as shaded tiles (Figure 12).
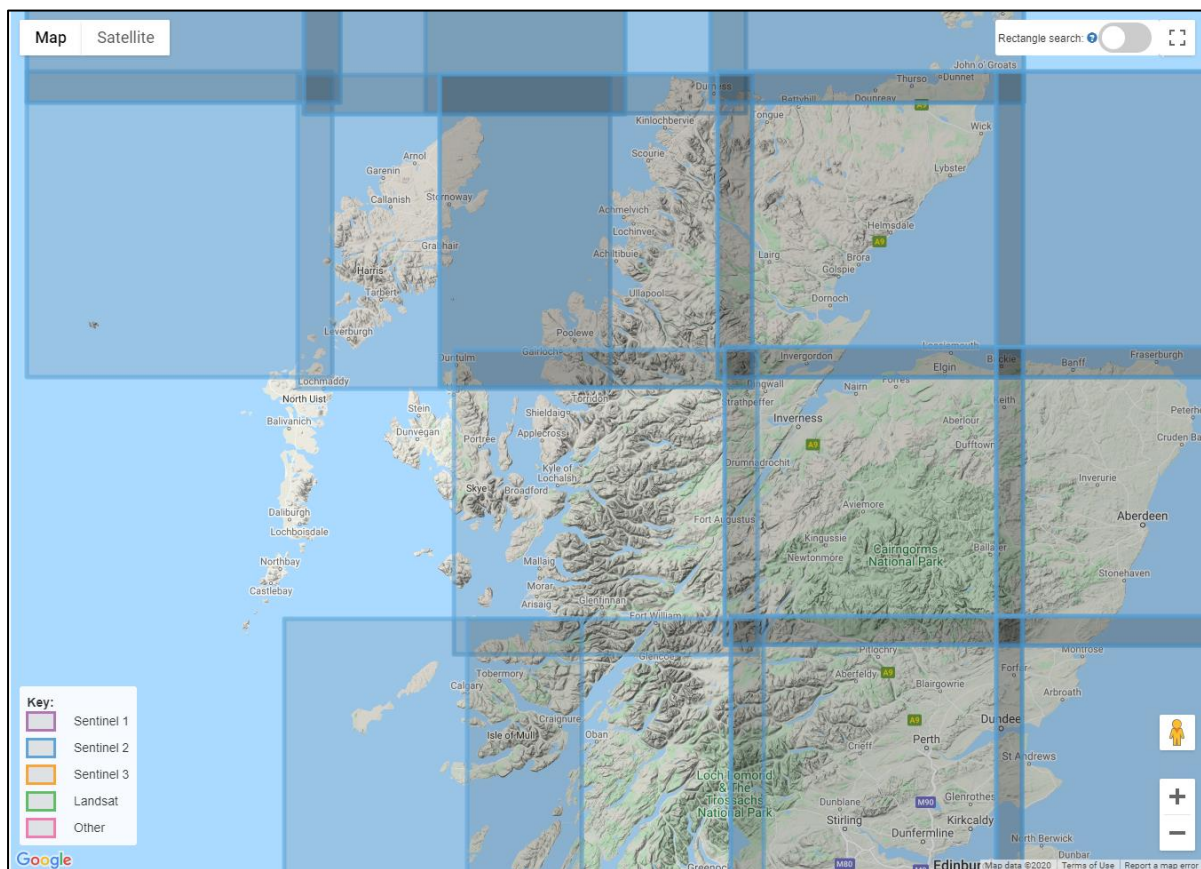
Figure 12: CEDA Satellite Data Finder interactive map showing the coverage of Sentinel-2A ARD over part of Scotland from the 1st to 7th February 2019

You can click on a shaded tile on the map to see the dataset filename, acquisition time and date and satellite details in a pop-up box (Figure 13). If there are multiple datasets available for that location and date range, information will only be shown for the top layer.
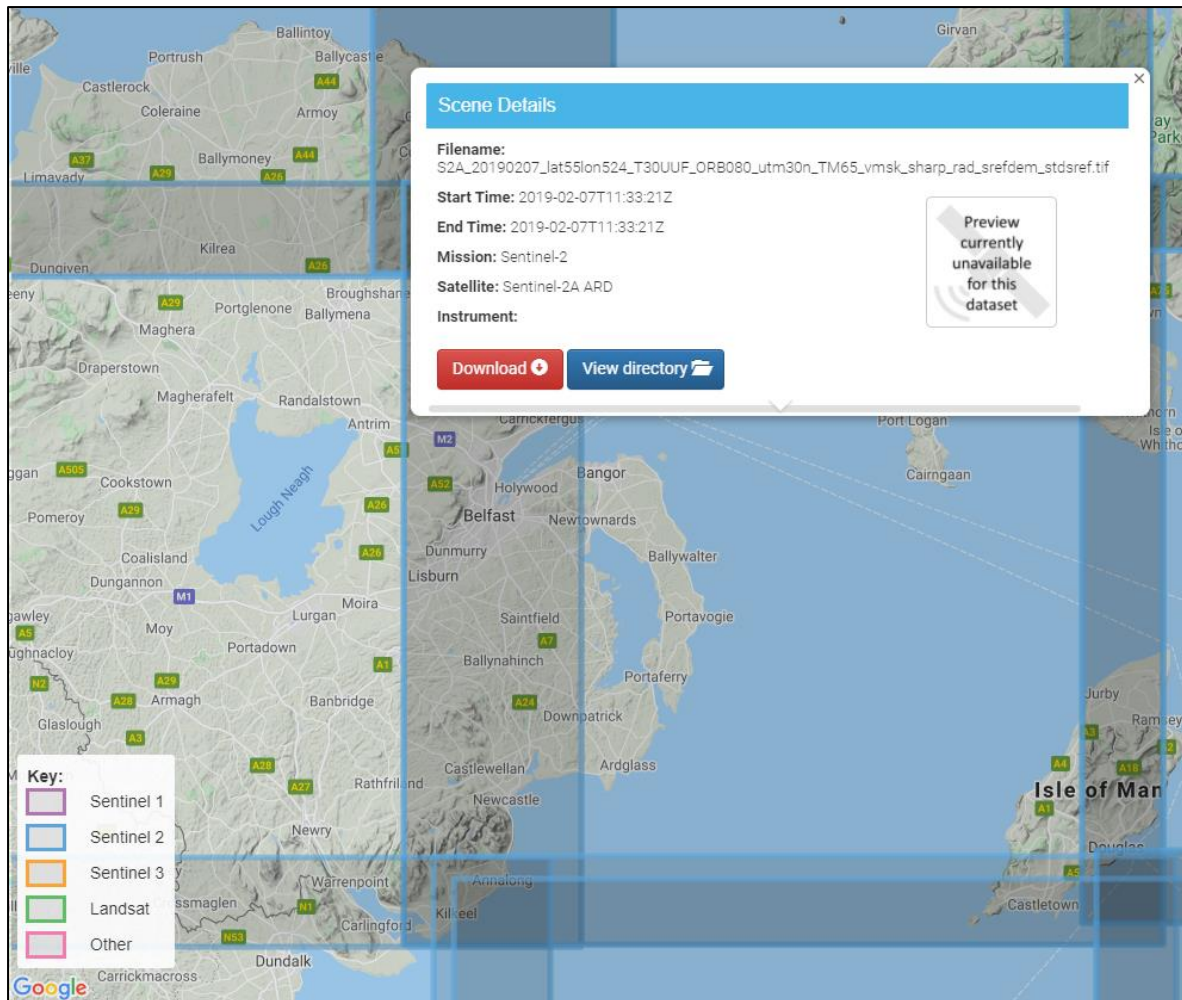
Figure 13: Sentinel-2 ARD dataset details obtained by clicking on a shaded tile on the interactive map

Click the Download [Download] button to download the imagery file from the dataset.

Click the View directory [View directory] button to navigate to the index page where you will find the complete dataset including ancillary files, as well as other ARD datasets captured by that satellite mission on that date.

Downloading data

Sentinel-1 and Sentinel-2 ARD can be downloaded via your internet browser by:

- Clicking the file name on an index page

- Clicking the download button [icon] on an index page

- Clicking the download button [Download] on the Satellite Data Finder

Any of the above actions will instantly start the process of downloading the selected file to your default download location.

To download imagery along with its metadata and ancillary files, for example the cloud shadow mask for Sentinel-2 data, each file must be downloaded separately by clicking the file name or download button on the index page.

Download speed will vary depending on your internet connection, but please note that the **ARD files are very large and may therefore take a long time to download**. For some users, the file sizes may exceed the limits set by their organisation's IT network. Analytical data users will find it more efficient to access data programmatically via API (application programming interface) or to access data directly using JASMIN. These options are outlined in the following sections.

Programmatic Data Access

OPeNDAP

OPeNDAP (Open-source Project for a Network Data Access Protocol) is the technology underpinning the CEDA Data Browser. It is also a scriptable interface enabling you to access data programmatically, for example using cURL or Python.

You can pull data directly into desktop GIS software using OPeNDAP and vsicurl, avoiding the need for manual data download.

The vsicurl command is constructed as follows:

/vsicurl/http://dap.ceda.ac.uk/neodc/sentinel-ard/data/<sensor>/<year>/<month>/<day>/<file name>

For example:

/vsicurl/http://dap.ceda.ac.uk/neodc/sentinel-ard/data/sentinel_1/2020/01/02/S1A_20200102_103_asc_180702_180727_VVVH_G0_GB_OSGB_RTCK_SpkRL.tif

The following example illustrates how to access a Sentinel-1 dataset using vsicurl, OPeNDAP and free open-source QGIS software.

On the CEDA index page, right click on a dataset file name and select 'copy link address' (Figure 14).
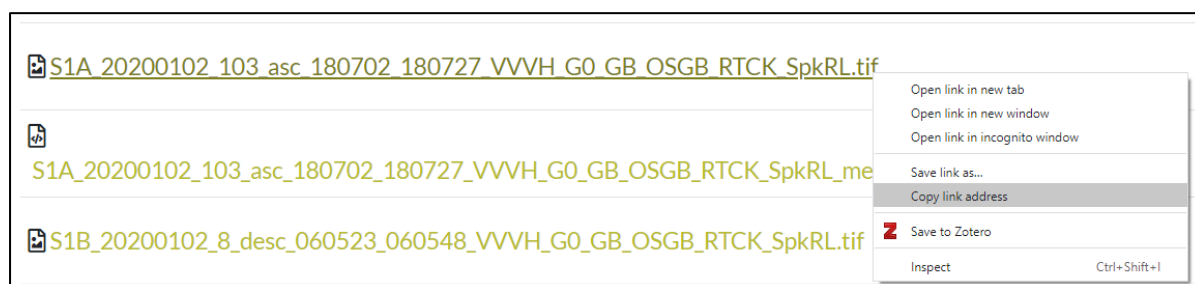
Figure 14: Copying the OPeNDAP server link address for a Sentinel-1 ARD data file

In QGIS, click the Open Data Source Manager icon or Layer >Add Raster Layer to open the Data Source Manager Raster dialogue box (Figure 15). Select 'Protocol: HTTP(S), cloud etc, paste the link address for the dataset into the URI box and click Add.
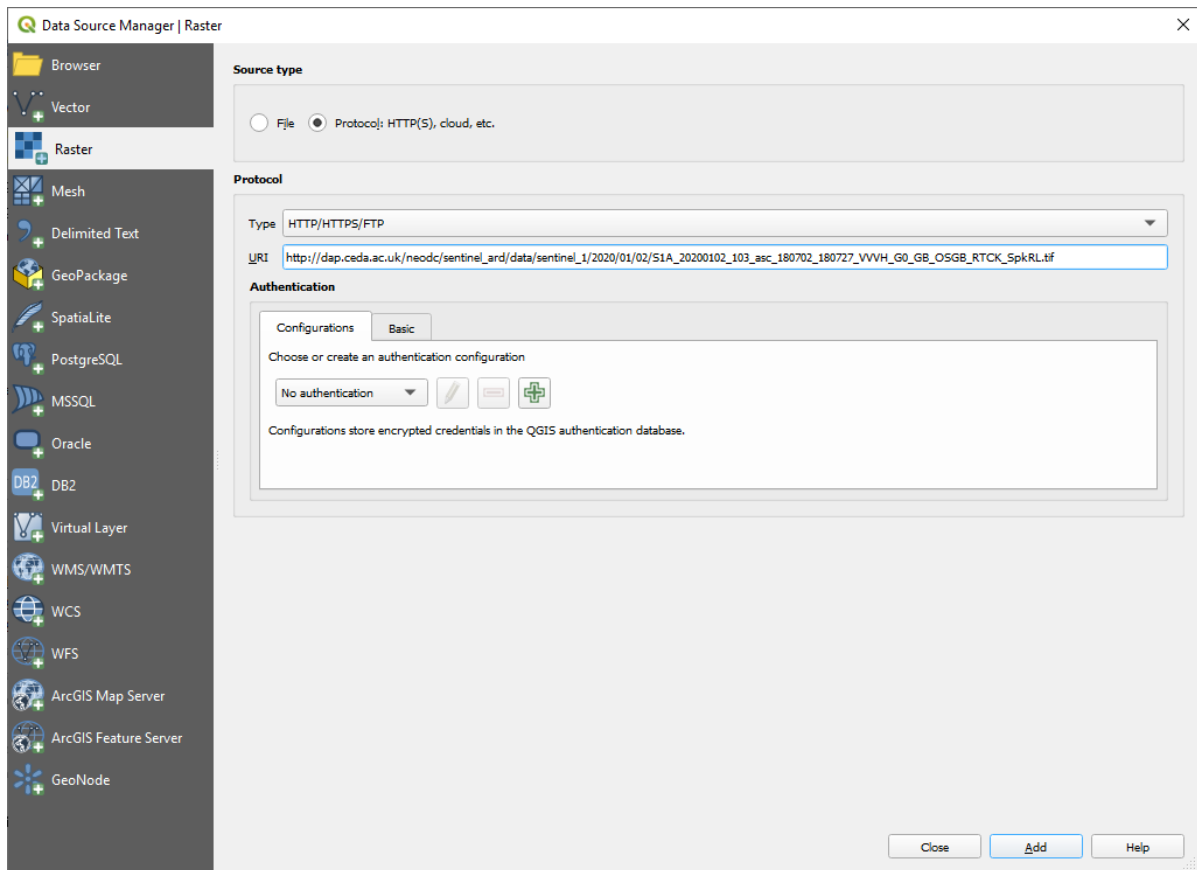
Figure 15: Adding a Sentinel-1 ARD dataset to QGIS using vsicurl and OPeNDAP

The dataset now appears in the Layers list and on the map in QGIS (Figure 16).
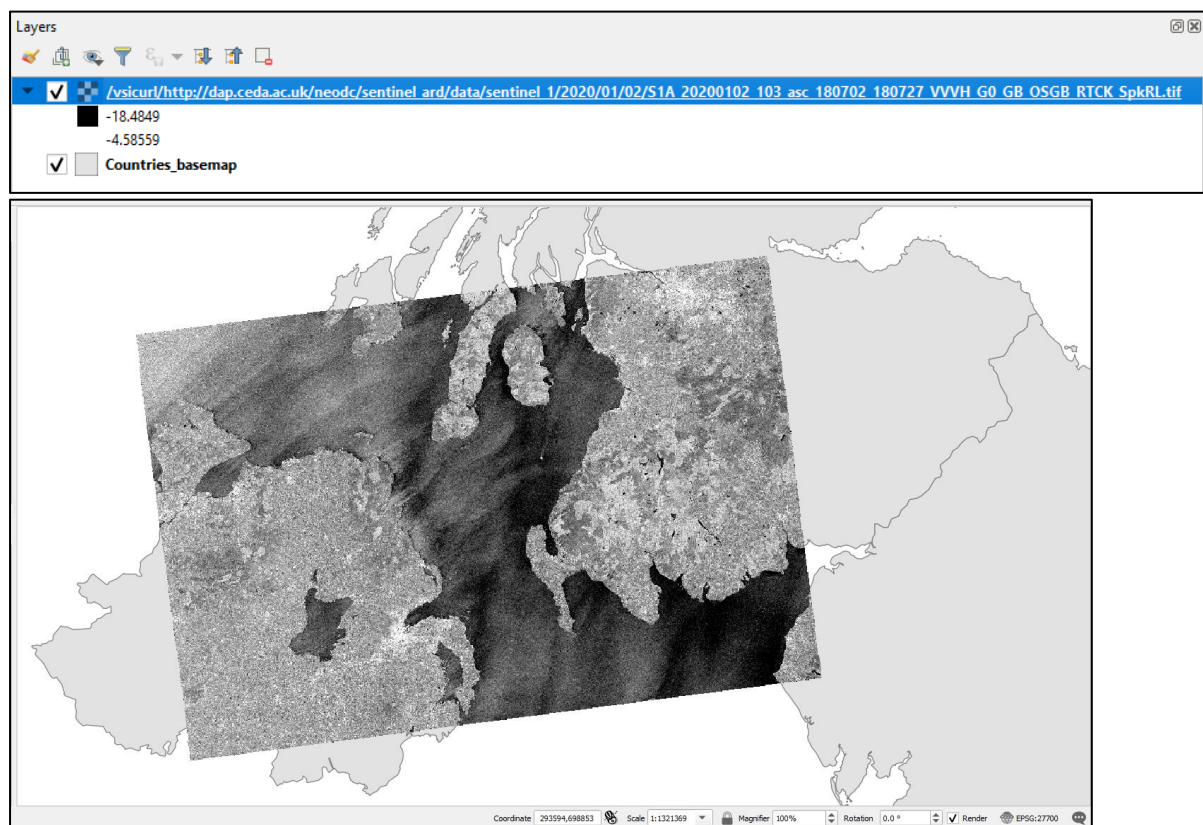
Figure 16: Sentinel-1 scene pulled into QGIS using vsicurl and OPeNDAP

Visit the CEDA help pages for further information on **CEDA OPeNDAP scripted interactions**.

FTP (File Transfer Protocol)

Registered CEDA users may access an FTP service, which is suitable for small to medium-scale data downloads. You can access the FTP service here:

ftp://ftp.ceda.ac.uk/

The CEDA Help Pages provide an introduction to **using FTP with the CEDA Archives**, including a list of common FTP commands. They also provide information on accessing data programmatically using FTP client libraries, with **example scripts in Python and PERL**.

Elasticsearch

CEDA uses Elasticsearch to improve the searchability of the CEDA Archive data holdings. It is the technology which underpins the Satellite Data Finder and the Catalogue Data Search interfaces. You can use the CEDA Elasticsearch Service to perform search and mapping operations via scripts or command line tools.

Visit the CEDA help pages for information on **interacting with Elasticsearch at CEDA** to search data holdings,

Direct Data Access

JASMIN

JASMIN is a 'super-data-cluster' administered by CEDA which delivers infrastructure for large-scale data analysis. It has 44 PB storage capacity in total. JASMIN provides direct access to the CEDA Archive, enabling users to carry out data processing and analysis 'next to the data', eliminating the need for data download. This is a highly efficient way of operating, and the most suitable approach for processing large volumes of data.

JASMIN offers scientific analysis servers (**Sci-servers**) where users can develop and test workflows interactively, as well as a batch processing environment (**LOTUS**) for running established workflows efficiently at scale. It also provides Group Workspaces (**GWS**), short-term network-accessible data storage allocations for specific projects, where users can collate data from external sources and from the CEDA Archive.

JASMIN also provides a cloud computing service, **JASMIN Cloud**, enabling users to consume compute resources or to provision their own virtual machines (**VMs**) within the JASMIN infrastructure for greater flexibility. JASMIN Cloud is co-located with the CEDA Archive and Group Workspaces.

To gain access to the JASMIN environment, you need to register on the JASMIN Accounts Portal and then request access to the services you require. See the JASMIN help pages for information on **getting started with JASMIN**.

For further information and queries about accessing the CEDA Archive via JASMIN, use the free-text search interface on the JASMIN help pages: **https://help.jasmin.ac.uk/**

JASMIN Notebook Service

The JASMIN Notebook Service was launched in 2020 and is currently in beta release. It is available to all registered JASMIN users and can be accessed here:

https://notebooks.jasmin.ac.uk/

The JASMIN Notebook Service allows users to write and run Python 3.7 Jupyter Notebooks in a browser, and offers direct read access to data on the CEDA Archive and Group Workspaces. This service is suitable for interactive data visualisation, not for high volume data processing.

For further information about the JASMIN Notebook Service, CEDA have provided:

- **Video of a 1-hour webinar** demonstrating the JASMIN Notebook Service
- **Help page** for the JASMIN Notebook Service
- **Set of Jupyter Notebooks** giving an introductory tour of the JASMIN Notebook Service

Data Licence and Terms of Use

Datasets provided through the Simple ARD Service are published under the Open Government Licence (OGL) v3 unless otherwise stated.

If you use data from the Simple ARD Service in a report, presentation or other publication, please acknowledge this with the following text:

> *"<Sentinel-1 / Sentinel-2> analysis-ready data processed by JNCC and supplied under the Open Government Licence v3 via the CEDA Archive [archive.ceda.ac.uk]."*

Data Quality

Comparative assessment of Sentinel-2 ARD

Prior to the launch of the Simple ARD Service, two assessments had been carried out to evaluate Sentinel-2 ARD produced by the ARCSI workflow.

1. Aberystwyth University compared Sentinel-2 ARD outputs with ESA ARD outputs as part of the original project on developing standards and automated production for Sentinel-2 ARD as detailed in the **final report**.
2. University College London compared surface reflectance values of Sentinel-2 ARD produced via three different atmospheric correction methods (ARCSI, Sen2Cor and SIAC) with AERONET ground measurements of surface reflectance as detailed in this **project presentation**.

This type of comparative analysis has not been applied to Sentinel-2 outputs on a routine basis since the launch of the Simple ARD Service; we assume all Sentinel-2 outputs are produced at the same quality as stated in the comparison exercises above.

To date, no such standardised comparative assessment has been carried out for Sentinel-1 ARD. There are no established methods for producing quality information on backscatter products – further research in this area would be beneficial.

Simple ARD Service QC Protocols

Visual assessment is carried out on a subset of Sentinel-1 and Sentinel-2 ARD produced by the Simple ARD Service. During initiation of the service and processing of the 12-month data catalogue, a selection of outputs were examined from <u>every swath</u>. Currently, during routine 'live' processing, a selection of outputs are examined from <u>every batch of swaths</u>, i.e. data captured over several days.

Visual assessment QC protocols for Sentinel-1 consist of opening the imagery in desktop GIS to ensure that:

- It is in the correct location with reference to a base map
- There are two bands
- Maximum and minimum values are negative
- Pixel size is 10m x 10m
- Projection is British National Grid (EPSG:27700) for Scotland data or Irish National Grid TM65 for Northern Ireland data
- Checking feature alignment with reference to Ordnance Survey vector data
- Check band responses, e.g. that band 1 has a higher value than band 2 and that topographically complex areas have higher values than topographically simple areas.

Visual assessment QC protocols for Sentinel-2 consist of opening the imagery and ancillary files in desktop GIS to ensure that:

- It is in the correct location with reference to a base map
- There are ten bands
- Pixel size is 10m x 10m
- Projection is British National Grid (EPSG:27700) for Scotland data or Irish National Grid TM65 for Northern Ireland data
- Checking feature alignment with reference to Ordnance Survey vector data
- Check the spectral reflectance curve of different land cover types e.g. bare soil, vegetation, surface water, urban.
- Check that the topographic shadow mask aligns with the imagery and has values of 1 (shadow) and NoData. An empty raster is expected in flat areas. Check that the shadows correspond to topographic features through comparison with the imagery or a Digital Elevation Model.
- Check that the cloud mask aligns with the imagery and has values of 1 (cloud), 2 (shadow) and NoData.

There are several known issues with Sentinel-1 and Sentinel-2 ARD which do not constitute QC failures. These are documented in the following sections.

If you encounter problems with the data which are not known issues, please report them to **earthobs@jncc.gov.uk**

Known issues with Sentinel-1 ARD

Terrain correction

Terrain correction with SNAP Toolbox does not produce accurate backscatter values in areas of steep slopes. Data is compromised on steep slopes which limits product creation and services for certain applications such as forestry. Improved tools for terrain correction within SNAP Toolbox are planned and could be evaluated upon release.

Radar Frequency Interference (RFI)

Radar Frequency Interference produces noise in data over areas where there are radar antennas on the ground (Figure 17). These can occur in any scene and there is no discernible time pattern. Data is compromised in the affected area and needs to be masked, but there is currently no method of producing a mask other than manual digitisation.
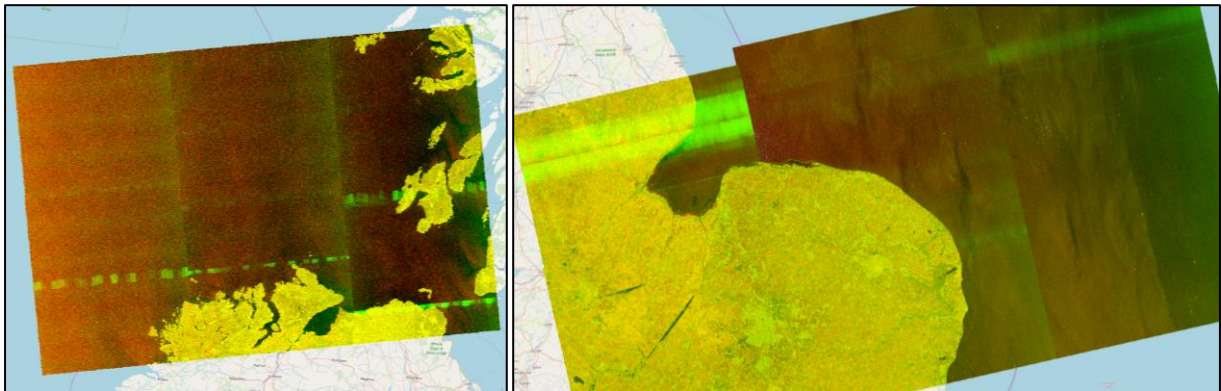
*Figure 17: Examples of Radar Frequency Interference (RFI) in Sentinel-1 ARD*

NoData artefacts

SNAP processing can cause NoData artefacts such as perpendicular stripes across the orbit path (Figure 18) or small scattered specks which seem only to occur over the sea (Figure 19). These are unavoidable with this processing method.
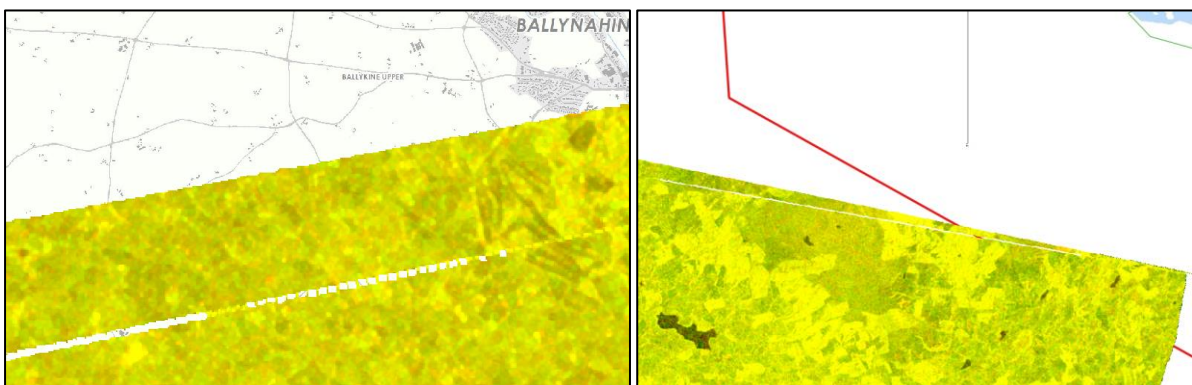
Figure 18: Perpendicular stripes caused by NoData values in Sentinel-1 ARD
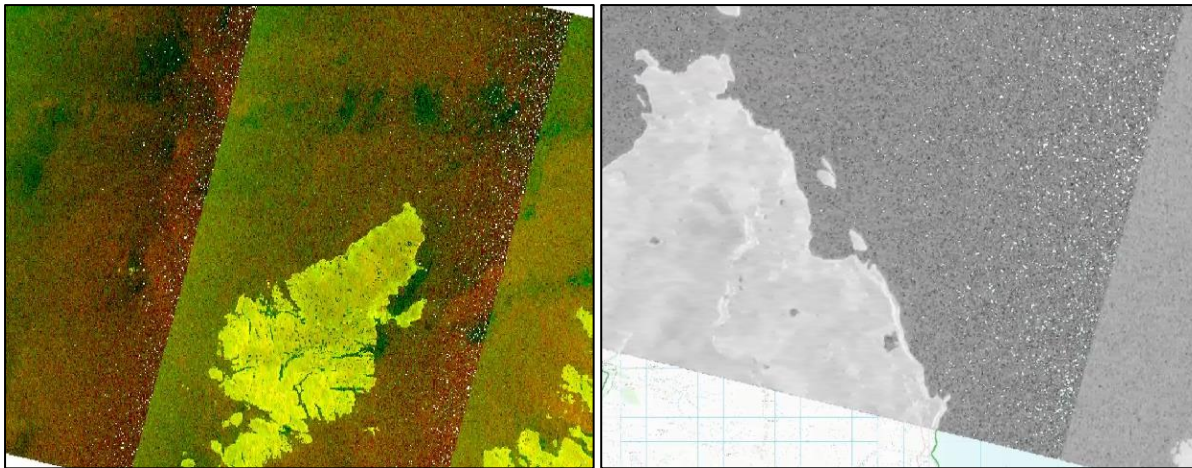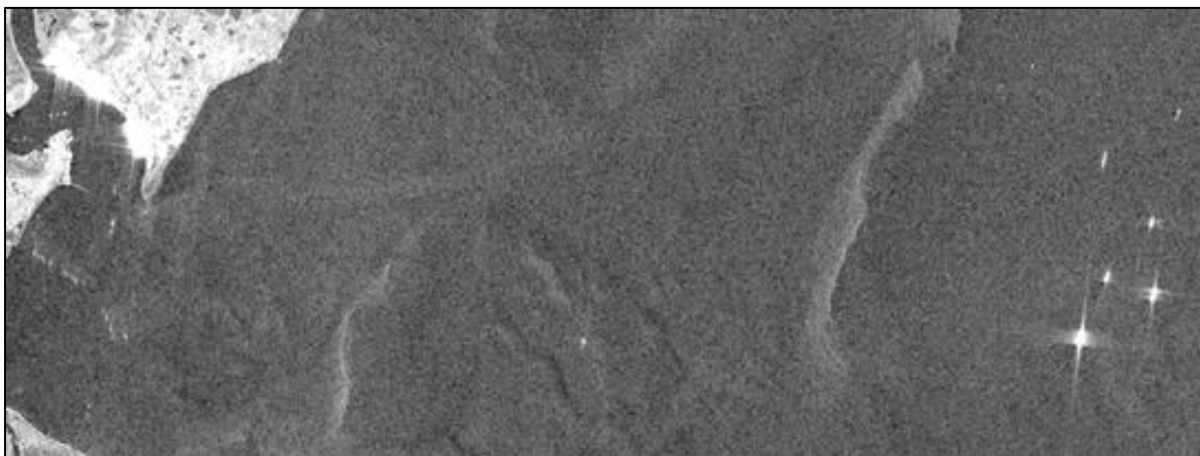
Figure 19: Scattered specks caused by NoData values over the sea in Sentinel-1 ARD

High backscatter 'flare'

Bright 'flare' can appear in imagery over areas of extremely high backscatter, such as the urban area and vessels at sea shown in Figure 20.

Figure 20: Example of flare over areas of high backscatter in Sentinel-1

# Known issues with Sentinel-2 ARD

Geometric accuracy

Geometric accuracy is poor in higher latitudes, which affects Scotland in particular and may result in misalignment with other spatial datasets. This issue can only be resolved by ESA through the creation of better ground control points for geometric correction.

Radiometric accuracy

Radiometric accuracy at sensor level is not known. This uncertainty limits the application of time-series analyses, because if radiometric changes over sensor lifetime are not flagged, any change detection analyses are at risk of detecting sensor change as opposed to real changes on the ground.

Cloud masking

Cloud masking is poor and produces masks with on average 73% overall accuracy. Sentinel-2 does not have a thermal band, so the cloud mask algorithm (Fmask) uses brightness and whiteness probability. This can result in over-prediction of cloud in built-up areas and on bare ground, particularly in winter (Figure 21). Cloud may also be under-predicted, notably over the sea (Figure 22). More recent versions of the current ARCSI cloud mask algorithm are available, but the significance of change to cloud mask outputs would need to be tested. Research into the implementation of multi-temporal cloud masking would also be beneficial.
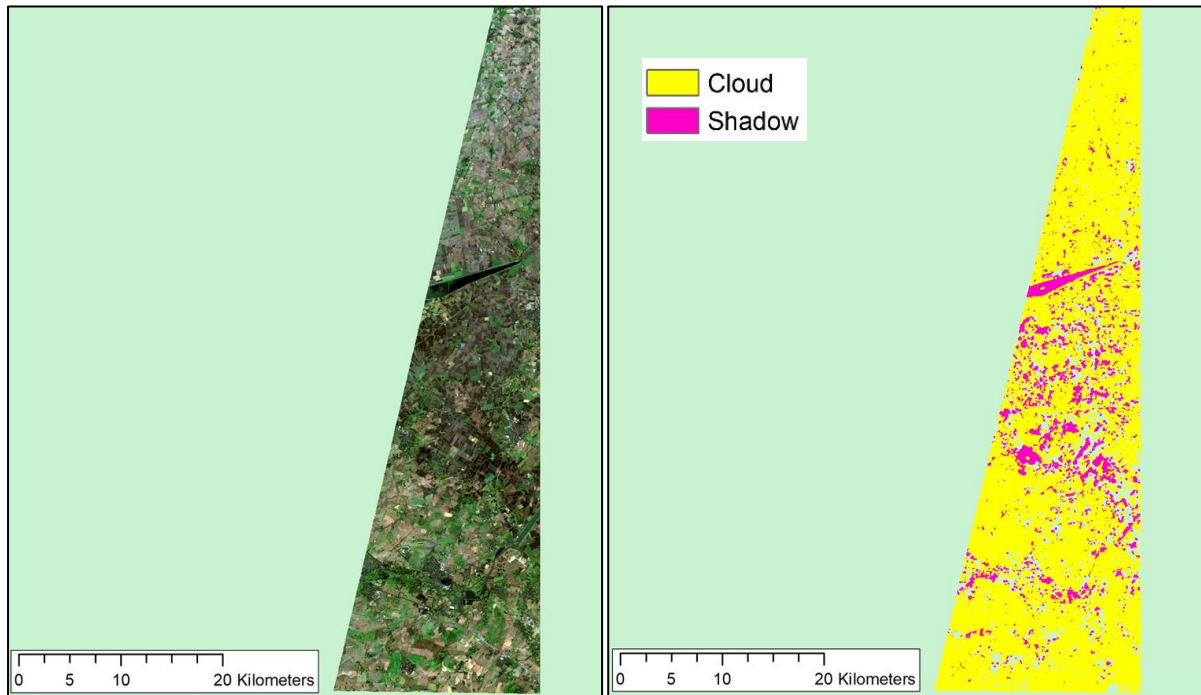

Figure 21: Over-prediction of cloud. In this imagery from December 2019, the predicted cloud cover is 86% but the real cloud cover is close to zero.
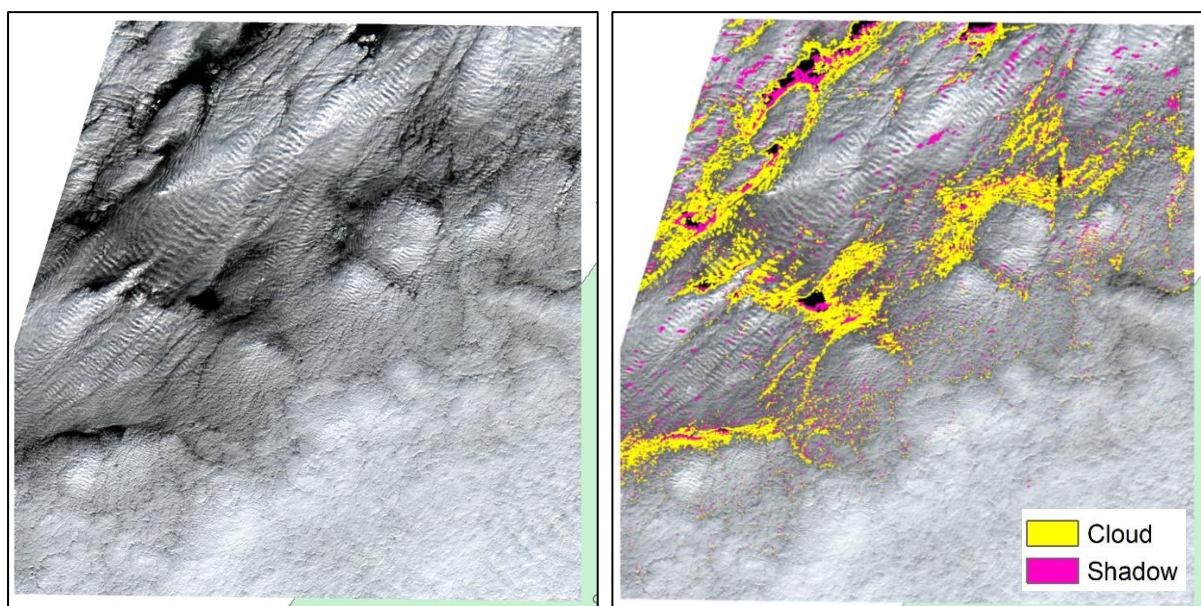
Figure 22: Under-prediction of cloud. In this imagery from January 2020 the predicted cloud cover is 13% but the real cloud cover is closer to 95%.

Edge pixel anomalies

Some granules have a single row of pixels with anomalous high or low values along one or more edges of the imagery (Figure 23). This is thought to be caused by topographic correction. Data is compromised and needs to be masked out, which can be achieved by mosaicking thanks to the overlap between adjacent granules. This issue may be resolved in future by upgrading to the latest version of ARCSI.
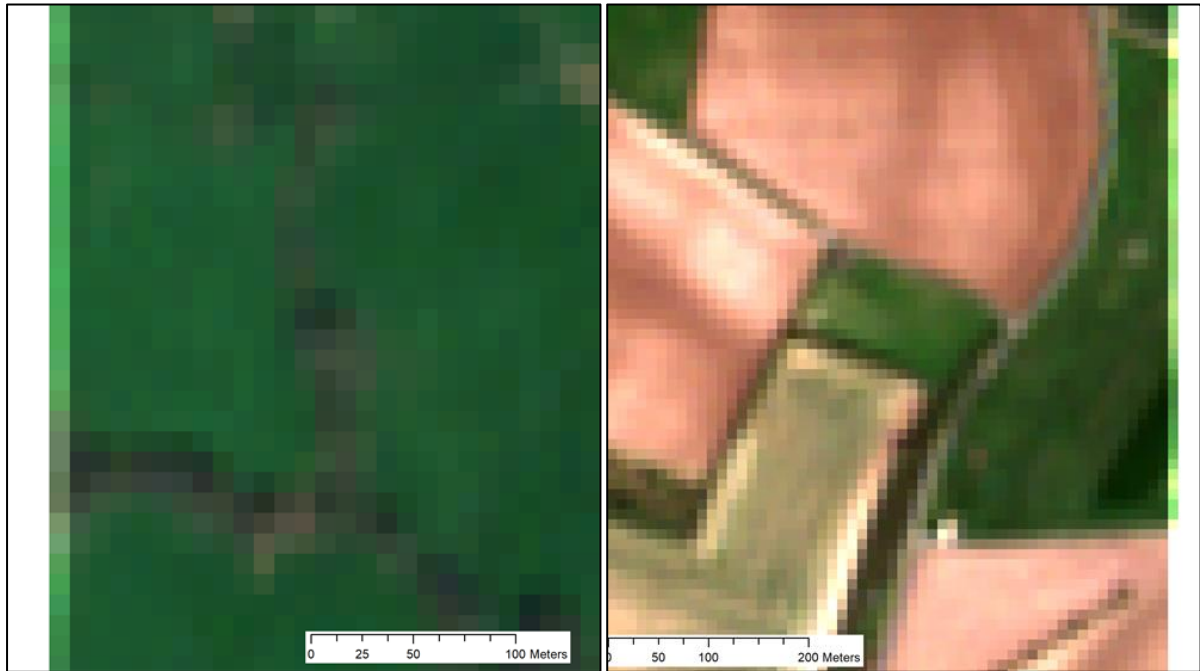
Figure 23: Example of pixels with anomalous values on the granule edge

Future Development

The automated processing chains that produce analysis-ready Sentinel-1 and Sentinel-2 data for the Simple ARD Service use open source software and may be adapted in future if better solutions become available and if resources can be obtained to implement them.

The most important components of ARD are consistency in the way that the outputs are produced and the communication of known issues to users. If better solutions become available and can be resourced, the following points would need to be considered:

- A test phase is required to determine if the change is significant enough to apply to the processing chain.
- If the change is significant, the product owner will need to consider whether all archive data needs to be re-processed.

Feedback and Further Assistance

We hope that you find the Simple ARD Service a valuable resource. We welcome your feedback and suggestions for improvement and will act on this as best we can. To provide feedback or report an issue, please contact **earthobs@jncc.gov.uk**.

Glossary

API	Application Programming Interface
ARCSI	Atmospheric and Radiometric Correction of Satellite Imagery
ARD	Analysis Ready Data
CEDA	Centre for Environmental Data Analysis
EO	Earth Observation
EODS	Defra's Earth Observation Data Service
ESA	European Space Agency
FTP	File Transfer Protocol
OPeNDAP	Open-source Project for a Network Data Access Protocol
S1	Sentinel-1
S2	Sentinel-2
SAR	Synthetic Aperture Radar
SNAP	Sentinel Application Platform

Appendix 1: Sentinel-1 spatial coverage

The Simple ARD Service provides Sentinel-1 data from seven ascending orbits and five descending orbits.

Top (left to right): ascending orbits 103, 59, 74, 30, 161, 1 and 132.

Bottom (left to right) descending orbits 23, 154, 96, 52 and 125.

Appendix 2: Sentinel-2 spatial coverage

The Simple ARD Service provides Sentinel-2 data from five orbits.

Top (left to right): orbits 23, 80 and 123, cover both Scotland and Northern Ireland.

Bottom (left to right) orbits 37 and 66 cover only Scotland.

The codes for the granules covering Northern Ireland and Scotland are shown on the following page.
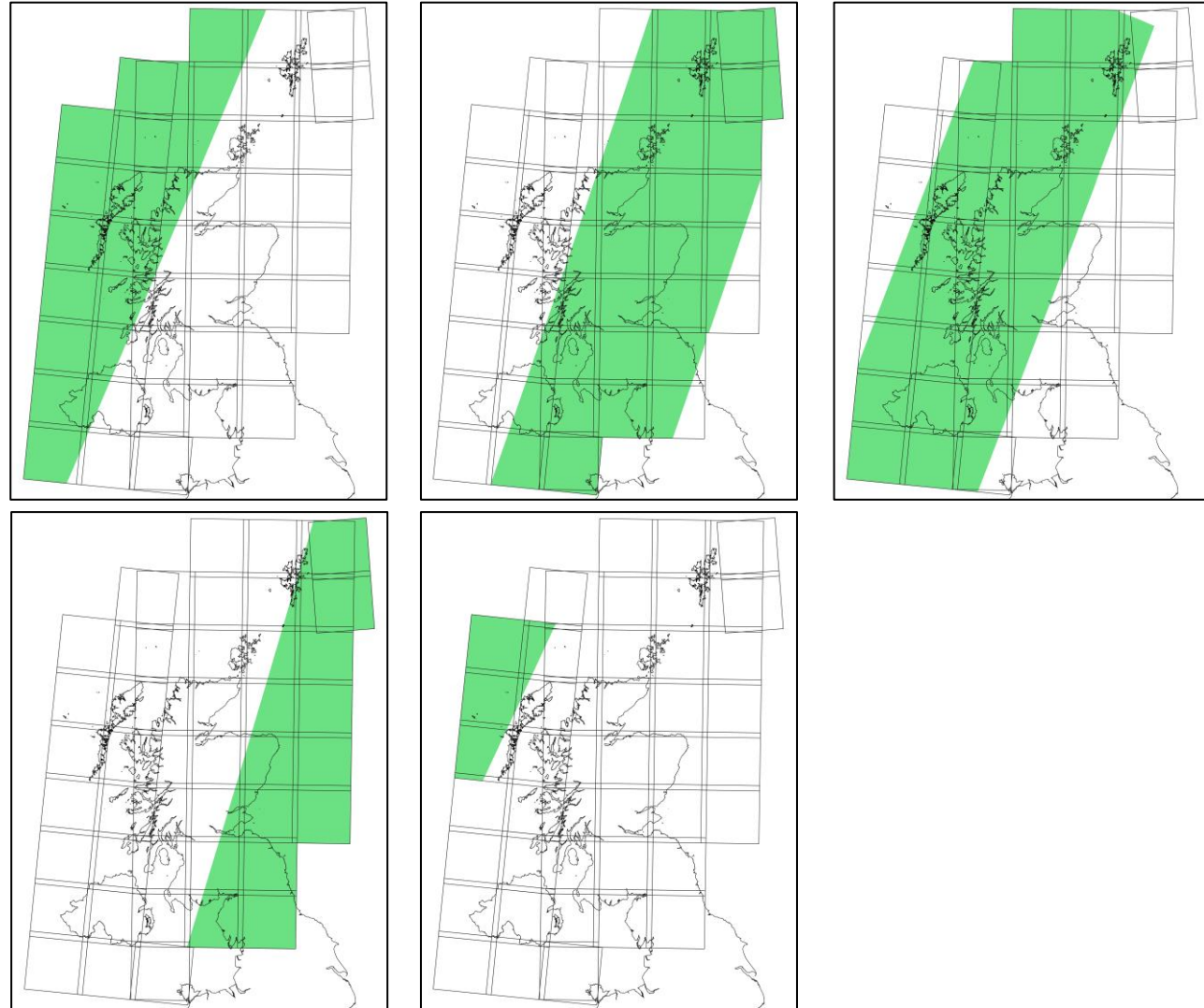
Northern Ireland is covered by ten granules (left) and Scotland is covered by 41 granules (right).

Each granule has a unique code beginning with the UTM zone, in this case 29, 30 or 31.

Granules 29UPB, 30UUG and 30UUF are processed twice by the Simple ARD Service, to produce outputs in the British National Grid and Irish National Grid systems.