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Standard course – Remote Sensing
Lesson SR2 – Main Data sources and types

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C.Domingo – CREAF

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- Types of platforms and sensors: Sentinel, Landsat, SPOT, MODIS
- Data types:
  - File format: GeoTIFF, NetCDF, HDF, IMG, JPEG2000
  - File format of the future: COG
- Data distribution
  - Distribution policies
  - Organization - Data hubs

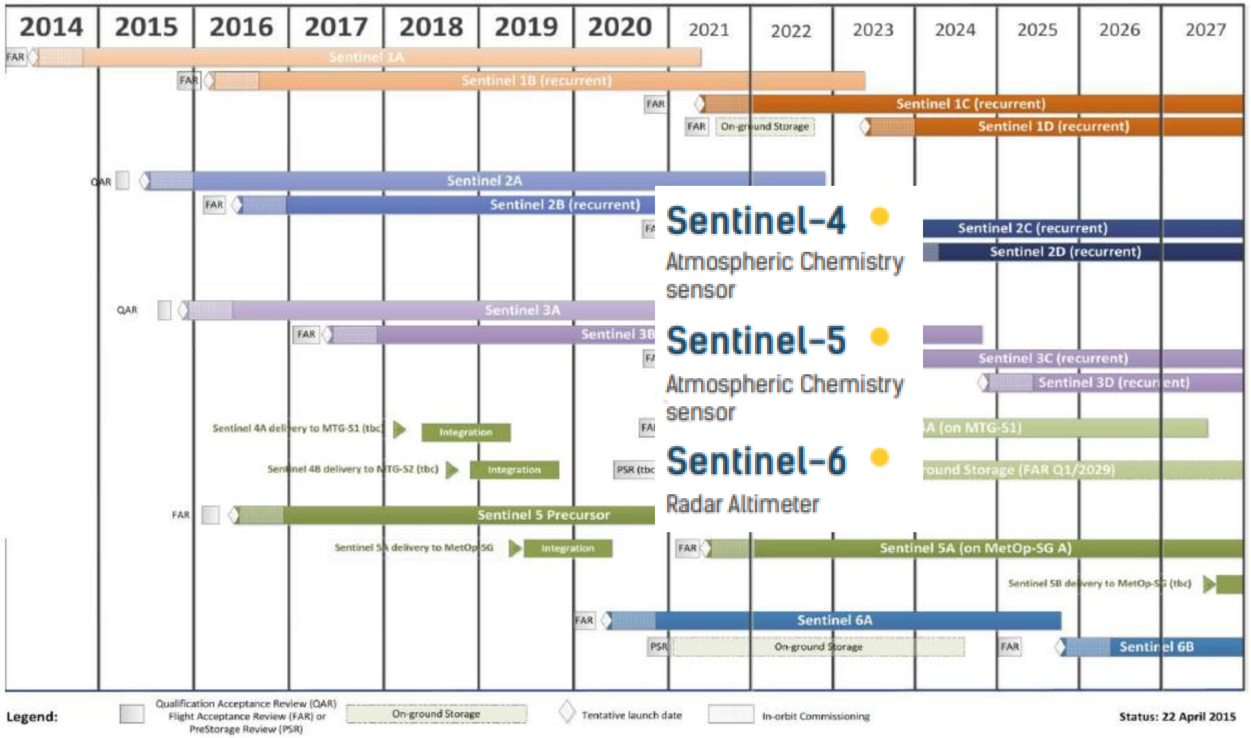
Platforms and sensors

CREAF

Types of missions and instruments

Type	Pseudocharacteristics	Examples
Scientific	High data quality Low Ground Sampling Distance (GSD) (absolute or relative) No image cost	Terra, Aqua (MODIS) SMOS FLEX
Operational	Robust data Continuity, accessibility of data Usually without image cost	Meteosat NOAA-POES, MetOp LANDSAT (TM, ETM, OLI) Sentinel-1,-2,-3
Comercial	High GSD Payment details	SPOT, Pleiades WorldView Planet-Dove

Sentinel



Sentinel-1A
Synthetic Aperture Radar

Sentinel-1B
Synthetic Aperture Radar

Sentinel-2A
Multi-spectral optical sensor

Sentinel-2B
Multi-spectral optical sensor

Sentinel-3A
Medium resolution optical sensor and Altimeter

Sentinel-3B
Medium resolution optical sensor and Altimeter

Sentinel-5P
Atmospheric Chemistry sensor

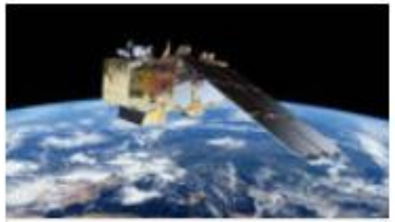
Sentinel-4
Atmospheric Chemistry sensor

Sentinel-5
Atmospheric Chemistry sensor

Sentinel-6
Radar Altimeter

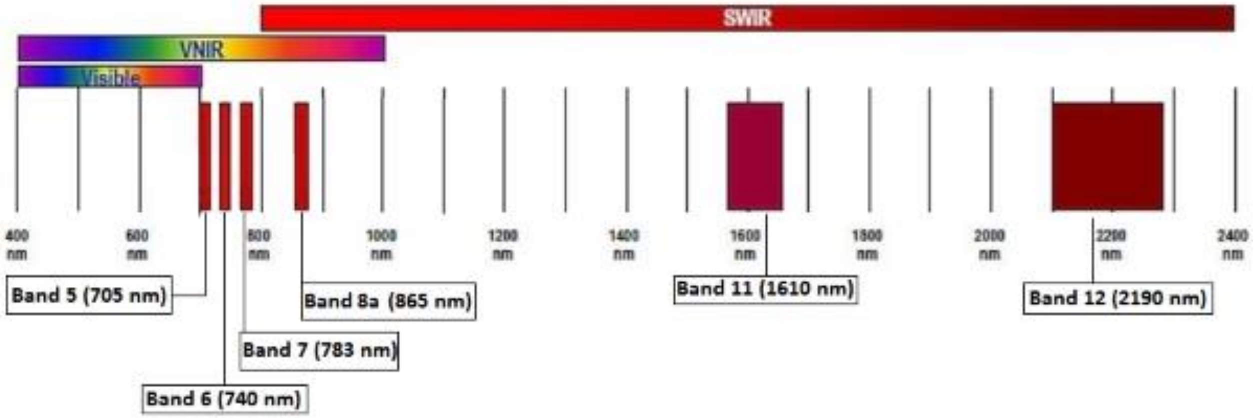
Sentinel

Sentinel-1



Sentinel-2

Sentinel-3



- **Sentinel-2** is a polar-orbiting, multispectral high-resolution imaging mission for land monitoring to provide, for example, imagery of vegetation, soil and water cover, inland waterways and coastal areas. Sentinel-2 can also deliver information for emergency services. Sentinel-2A was launched on 23 June 2015 and Sentinel-2B followed on 7 March 2017.

- **Sentinel-3** is a multi-instrument mission to measure sea-surface topography, sea- and land-surface temperature, ocean colour and land colour with high-end accuracy and reliability. The mission will support ocean forecasting systems, as well as environmental and climate monitoring. Sentinel-3A was launched on 16 February 2016.

Sentinel-1

- The **Sentinel-1** mission comprises a constellation of two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar imaging, enabling them to acquire imagery regardless of the weather.
- **Sentinel-1** carries a single C-band synthetic aperture radar instrument operating at a centre frequency of 5.405 GHz. It includes a right-looking active phased array antenna providing fast scanning in elevation and azimuth, data storage capacity of 1 410 Gb and 520 Mbit/s X-band downlink capacity.
- The C-SAR instrument supports operation in dual polarisation (HH+HV, VV+VH) implemented through one transmit chain (switchable to H or V) and two parallel receive chains for H and V polarisation. Dual polarisation data is useful for land cover classification and sea-ice applications.

Sentinel

- **Sentinel-2**, launched as part of the European Commission's Copernicus program on June 23, 2015, was designed specifically to deliver a wealth of data and imagery.
- The satellite is equipped with an opto-electronic multispectral sensor for surveying with a Sentinel-2 resolution of 10 to 60 m in the visible, near infrared (VNIR), and short-wave infrared (SWIR) spectral zones, including 13 spectral channels, which ensures the capture of differences in vegetation state, including temporal changes, and also minimizes impact on the quality of atmospheric photography.
- The orbit is an average height of 785 km and the presence of two satellites in the mission allow repeated surveys every 5 days at the equator and every 2-3 days at middle latitudes.

Sentinel-3

- The main objective of the **Sentinel-3** mission is to measure sea surface topography, sea and land surface temperature, and ocean and land surface colour with high accuracy and reliability to support ocean forecasting systems, environmental monitoring and climate monitoring.
- The **Sentinel-3** satellite carries the following payload instruments:
  - a push-broom imaging spectrometer instrument called the Ocean and Land Colour Instrument (OLCI) 21 bands [0.4-1.02] µm, 300 m
  - a dual view (near-nadir and backward views) conical imaging radiometer called the Sea and Land Surface Temperature Radiometer (SLSTR) instrument, 9 bands [0.55-12] µm, 500 m (VIS, SWIR), 1 km (MWIR, TIR)
  - a dual-frequency SAR altimeter called the SAR Radar ALtimeter (SRAL) instrument 1.9 KHz (LRM), 17.8 KHz (SAR)
  - a Microwave Radiometer (MWR) instrument, supporting the SRAL in achieving overall altimeter mission performance by providing wet atmosphere correction, 23.8 / 36.5 GHz
  - a Precise Orbit Determination package including a Global Navigation Satellite Systems (GNSS) instrument, a Doppler Orbit determination and Radio-positioning Integrated on Satellite (DORIS) instrument and a Laser Retro-Reflector (LRR).

Sentinel-4

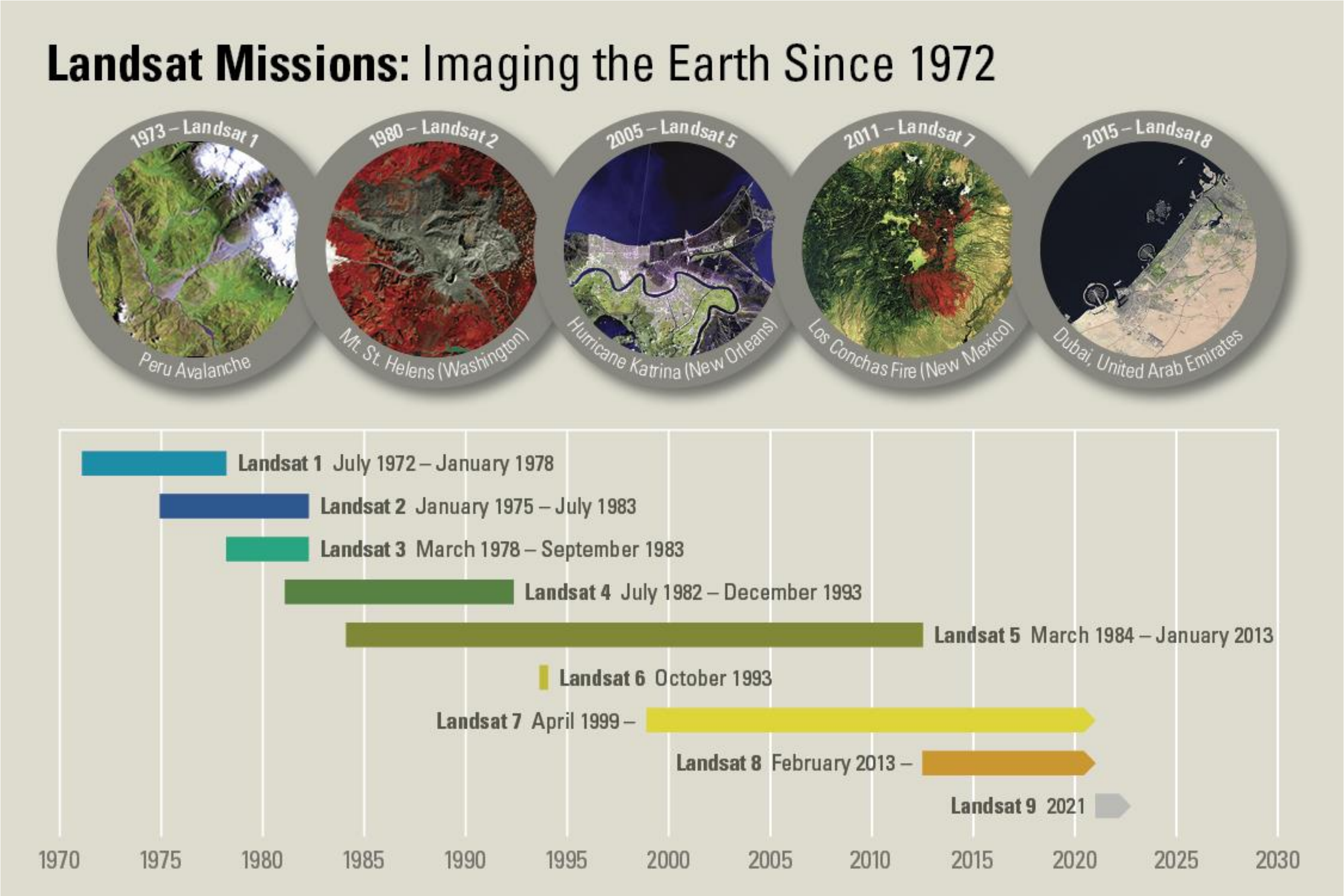
- The main objective of the **Sentinel-4** mission is to monitor key air quality trace gases and aerosols over Europe in support of the Copernicus Atmosphere Monitoring Service (CAMS) at high spatial resolution and with a fast revisit time.
- The Space Segment of the Sentinel-4 mission consists of an Ultraviolet-Visible-Near-Infrared (UVN) light imaging spectrometer instrument embarked on the Meteosat Third Generation Sounder (MTG-S) satellite.
- 3 Ultraviolet (305-400 nm), Visible (400-500 nm) and Near Infrared(750-775 nm) VIS and NIR bands implemented in two spectrometers UVVIS & NIR), 8x8 km2, revisit time 60 min.

Sentinel-5

- The Copernicus Space Component comprises a series of space-borne missions called 'Sentinels' that are developed and procured by the European Space Agency. The missions Sentinel-4, -5 and -5 precursor (S4, S5, S5P, respectively) are conceived as complementary elements of a constellation serving the specific needs of the Copernicus Atmospheric Monitoring Services (CAMS).
- The **Sentinel-5** mission consists of high resolution spectrometer system operating in the ultraviolet to shortwave infrared range with 7 different spectral bands: UV-1 (270-300nm), UV-2 (300-370nm), VIS (370-500nm), NIR-1 (685-710nm), NIR-2 (745-773nm), SWIR-1 (1590-1675nm) and SWIR-3 (2305-2385nm). The instrument will be carried on the MetOp-SG A satellite.
- 5 spectrometers (1 in UV1, 1 in UV2VIS, 1 in NIR, 2 in SWIR), 50 km, 7.5 km

Landsat

- The NASA/USGS Landsat Program provides the longest continuous space-based record of Earth's land in existence. Landsat data give us information essential for making informed decisions about Earth's resources and environment.

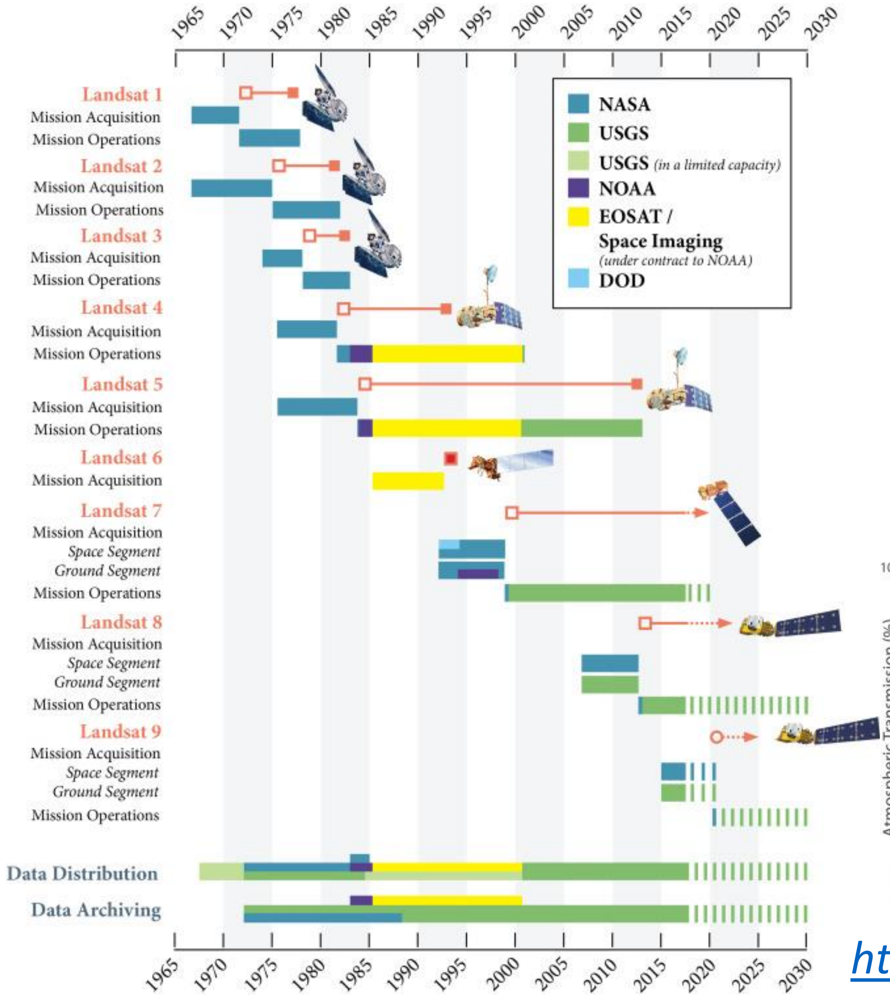


Source: USGS https://www.usgs.gov/landsat-missions/landsat-satellite-missions

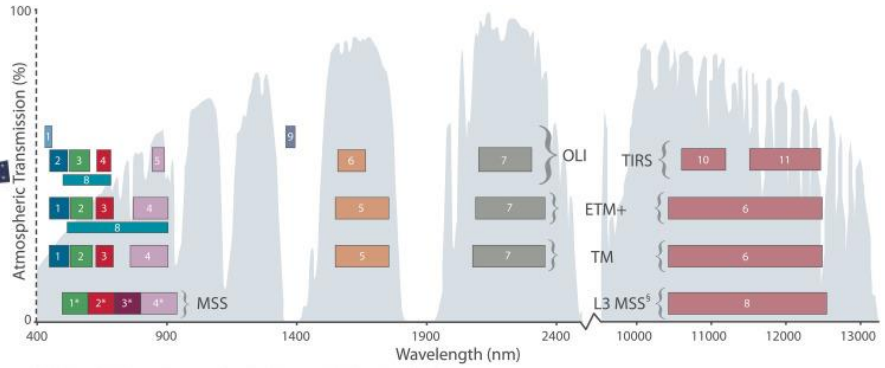
Landsat

- The Landsat Missions are comprised of eight Earth-observing operational satellites that use remote sensors to collect data and image our planet as a part of the U.S. Geological Survey (USGS) National Land Imaging (NLI) Program.
- Landsat 1 was launches in 1972. The launches of Landsat 2, Landsat 3, and Landsat 4 followed in 1975, 1978, and 1982, respectively. When Landsat 5 launched in 1984, no one could have predicted that the satellite would deliver high quality, global data of Earth's land surfaces for 28 years and 10 months. This officially set a new Guinness World Record for "longest-operating Earth observation satellite." Landsat 6 failed to achieve orbit in 1993. As a result of the lost mission, the satellite is not included in successful Landsat counts. The remainder of Landsat satellites have proved successful launches and data collection: Landsat 7 in 1999, Landsat 8 in 2013, and Landsat 9 in September 2021.

Landsat Missions



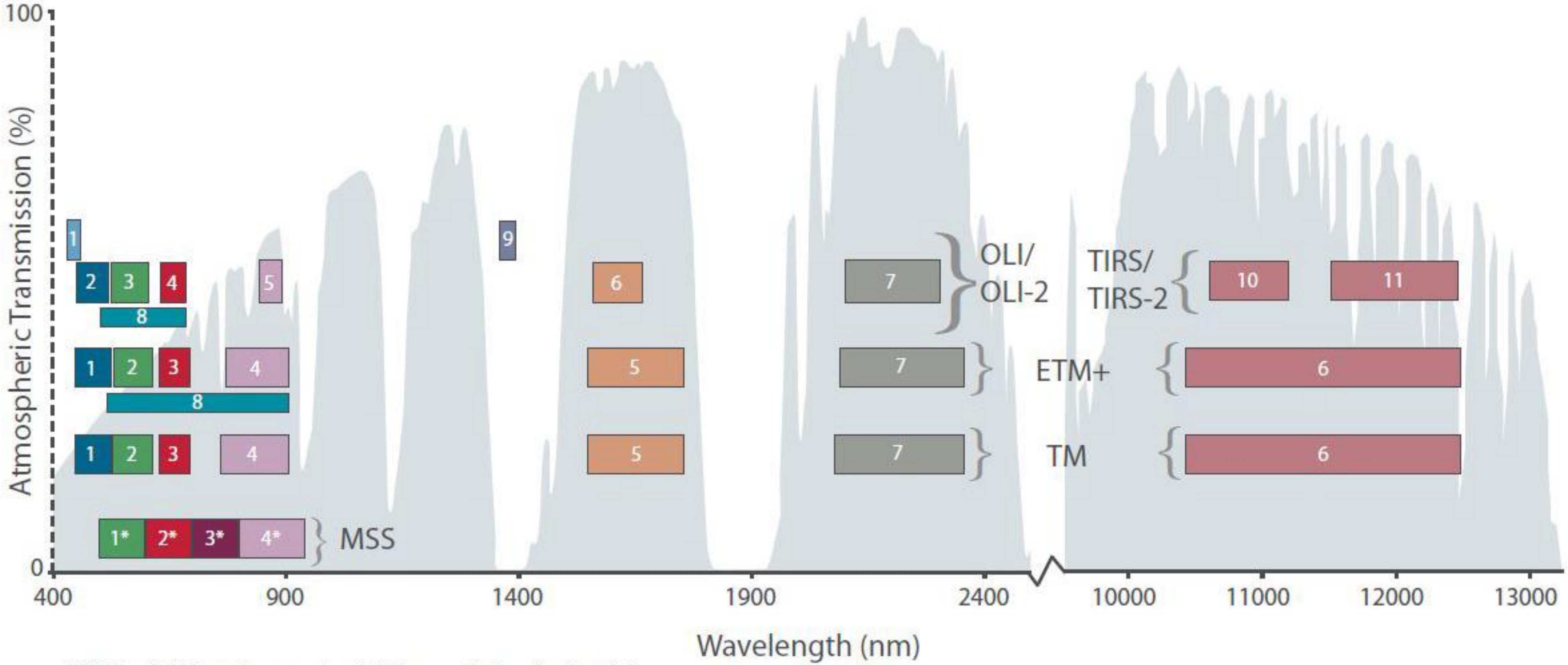
Landsat-7 ETM+ Bands (μm)			Landsat-8 OLI and *TIRS* Bands (μm)		
			30 m Coastal/Aerosol	0.435 - 0.451	Band 1
Band 1	30 m Blue	0.441 - 0.514	30 m Blue	0.452 - 0.512	Band 2
Band 2	30 m Green	0.519 - 0.601	30 m Green	0.533 - 0.590	Band 3
Band 3	30 m Red	0.631 - 0.692	30 m Red	0.636 - 0.673	Band 4
Band 4	30 m NIR	0.772 - 0.898	30 m NIR	0.851 - 0.879	Band 5
Band 5	30 m SWIR-1	1.547 - 1.749	30 m SWIR-1	1.566 - 1.651	Band 6
Band 6	60 m TIR	10.31 - 12.36	*100 m TIR-1*	*10.60 – 11.19*	Band 10
			100 m TIR-2	*11.50 – 12.51*	Band 11
Band 7	30 m SWIR-2	2.064 - 2.345	30 m SWIR-2	2.107 - 2.294	Band 7
Band 8	15 m Pan	0.515 - 0.896	15 m Pan	0.503 - 0.676	Band 8
			30 m Cirrus	1.363 - 1.384	Band 9



https://doi.org/10.1016/j.rse.2019.02.015

Landsat

- Spectral bandpasses for all Landsat Sensors.



* MSS bands 1–4 were known as bands 4–7, respectively, on Landsats 1–3

Source: USGS https://www.usgs.gov/media/images/spectral-bandpasses-all-landsat-sensors

Comparison Landsat-8 and Sentinel-2

16 days revisit time

Operational Land Imager (OLI) Landsat-8

Swath: 180 km
Pixel size: 30 m (B1, B2, B3, B4, B5, B6, B7, B9);
15 m (Panchromatic (B8));
Scanning system: Pushbroom
Radiometric resolution: 16-bits
Solar spectrum number of bands: 9
Spectral range (µm): 0.4-2.3

Thermal bands (TIRS sensor):
100 m ((B10, B11), 8 µm – 12 µm)

5 days constellation revisit time

Multispectral Imager (MSI) Sentinel-2A and Sentinel-2B

Swath: 290 km
Pixel size: 10 m (B2, B3, B4, B8);
20 m (B5, B6, B7, B8a, B11, B12);
60 m (B1, B9, B10)
Scanning system: Pushbroom
Radiometric resolution: 16-bits
Solar spectrum number of bands: 13
Spectral range (µm): 0.4-2.3

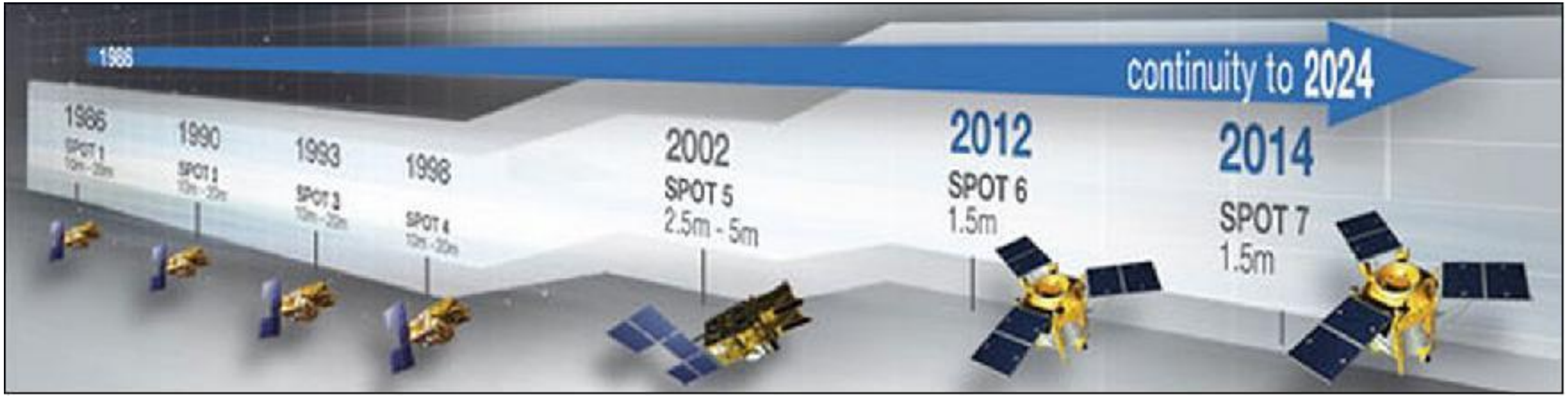
16

SPOT

• Main characteristics:

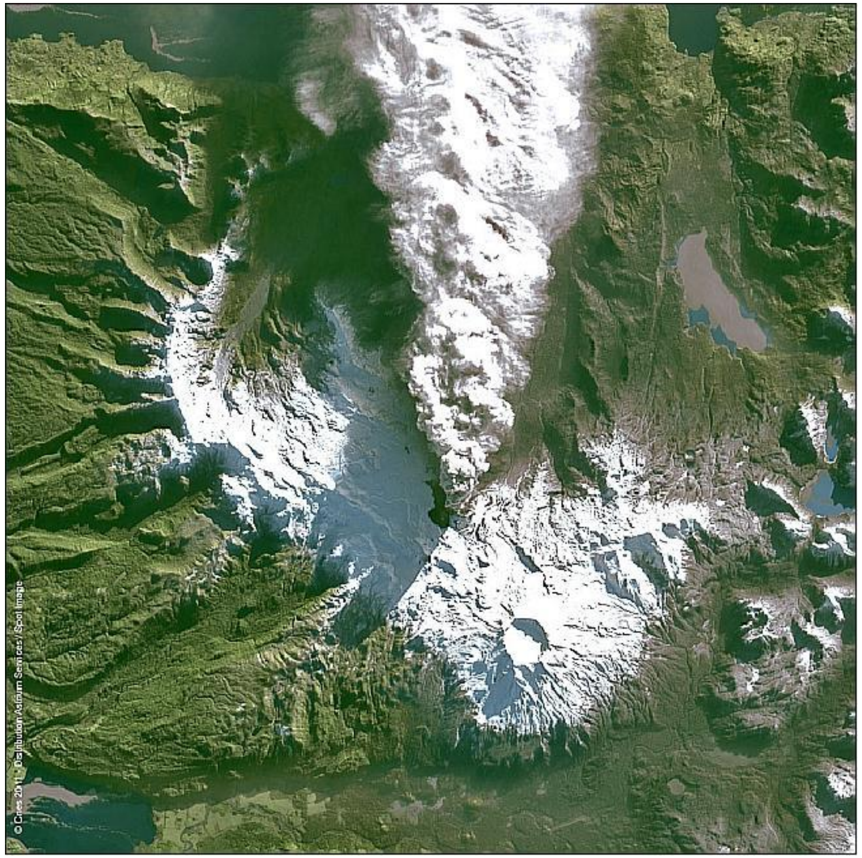
Satellite	Launch Year	No. of MS bands [nominal resolution]	Panchromatic resolution (nominal)	Altitude (km)	Revisit time (days)
SPOT 1	1986	3 [20 m]	1 [10 m]	832	2-3
SPOT 2	1990	3 [20 m]	1 [10 m]	832	2-3
SPOT 3	1993	3 [20 m]	1 [10 m]	832	2-3
SPOT 4	1998	4 [20 m]	1 [10 m]	832	2-3
SPOT 5	2002	4 [10 m]	1 [2.5-5 m]	822	2-3
SPOT 6	2012	4 [6 m]	1 [1.5 m]	694	1
SPOT 7	2014	4 [6 m]	1 [1.5 m]	694	1

Mission operators	SPOT 1-5: CNES SPOT-6/-7: Airbus Defence and Space
Launch dates	First launch: 22 February 1986 Last launch: 30 June 2014
Orbit altitude	SPOT 1-5: 832 km SPOT 6-7: 694 km
Orbit type	Sun-synchronous
Repeat cycle, spatial resolution, swath width	26 days, from 20 m to 1.5 m, 60 km
Onboard sensors provided under ESA's TPM (Third Party Mission) program	HRV, HRVIR, HRG and NAOMI
All of the SPOT satellites provide imagery in panchromatic and multispectral bands with a swath of 60 km. SPOT-6 and SPOT-7, will assure data continuity through to 2024.	

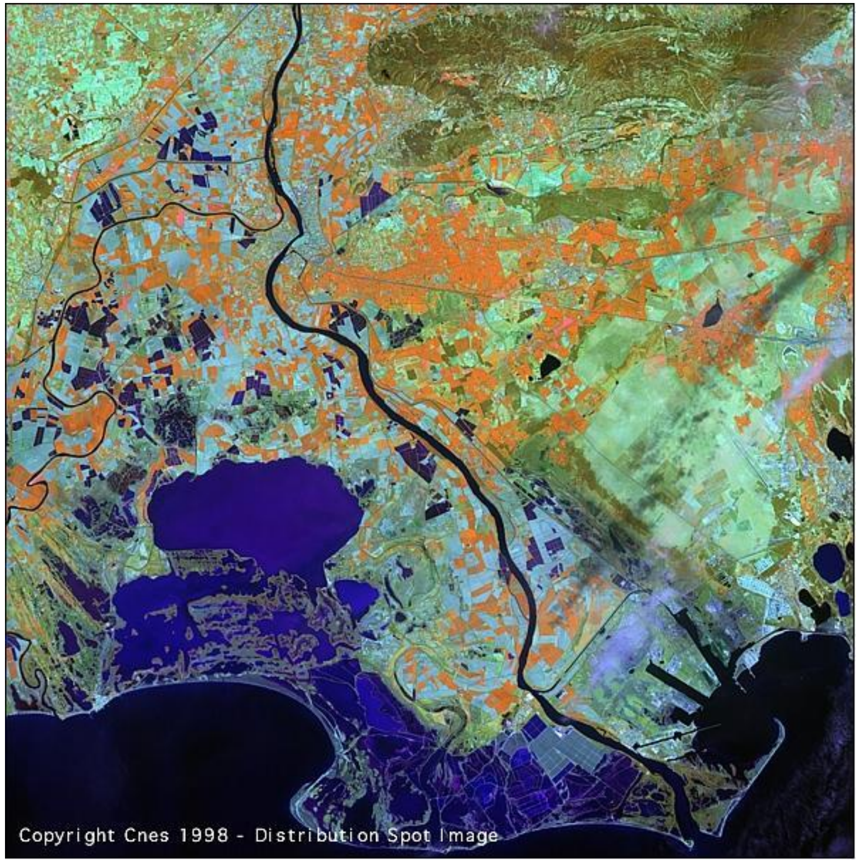


SPOT

- Examples:



SPOT-4 image (June 25, 2011) of the Puyehue-Cordón Caulle volcano range 800 km south of Santiago, Chile (image credit: Astrium Geo-Information Services)



This early SPOT 4 image represents the lower Rhone valley (France) and its delta on the Mediterranean (image credit: CNES, Spot Image)

MODIS

- Acronym for Moderate-Resolution Imaging Spectroradiometer.
- A remote sensing sensor installed on the Terra and Aqua satellites, mainly used to study land and ocean surface temperature, primary productivity, vegetation cover, cloud cover, aerosols, water vapour, temperature profiles and fires.
- It allows obtaining images in the spectral regions of VIS, NIR, SWIR, MWIR and LWIR with a spatial resolution at nadir of 250 m in VIS and NIR (bands 1 and 2), 500 m in VIS, NIR and SWIR (bands 3 to 7) and 1000 m in VIS, NIR, SWIR, MWIR and LWIR (bands 8 to 36). The scans have a radiometric resolution of 12 bits, are captured with cross track scanning technology and are distributed with a territorial coverage of about 2330 km (swath). The temporal resolution is between 1 and 2

MODIS

Specifications

Orbit: 705 km, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (Aqua), sun-synchronous, near-polar, circular

Scan Rate: 20.3 rpm, cross track

Swath Dimensions: 2330 km (cross track) by 10 km (along track at nadir)

Telescope: 17.78 cm diam. off-axis, afocal (collimated), with intermediate field stop

Size: 1.0 x 1.6 x 1.0 m

Weight: 228.7 kg

Power: 162.5 W (single orbit average)

Data Rate: 10.6 Mbps (peak daytime); 6.1 Mbps (orbital average)

Quantization: 12 bits

Spatial Resolution: 250 m (bands 1-2), 500 m (bands 3-7), 1000 m (bands 8-36) Design Life: 6 years

MODIS

[1]Bands 1 to 19 (nm); 20 to 36 (µm)

- Bands TERRA

Primary Use	Band	Bandwidth[1]
Land/Cloud/Aerosols Boundaries	1	620 - 670
	2	841 - 876
Land/Cloud/Aerosols Properties	3	459 - 479
	4	545 - 565
	5	1230 - 1250
	6	1628 - 1652
	7	2105 - 2155
Ocean Color/ Phytoplankton/ Biogeochemistry	8	405 - 420
	9	438 - 448
	10	483 - 493
	11	526 - 536
	12	546 - 556
	13	662 - 672
	14	673 - 683
	15	743 - 753
	16	862 - 877
Atmospheric Water Vapor	17	890 - 920
	18	931 - 941
	19	915 - 965

Primary Use	Band	Bandwidth[1]
Surface/Cloud Temperature	20	3.660 - 3.840
	21	3.929 - 3.989
	22	3.929 - 3.989
	23	4.020 - 4.080
Atmospheric Temperature	24	4.433 - 4.498
	25	4.482 - 4.549
Cirrus Clouds Water Vapor	26	1.360 - 1.390
	27	6.535 - 6.895
	28	7.175 - 7.475
Cloud Properties	29	8.400 - 8.700
Ozone	30	9.580 - 9.880
Surface/Cloud Temperature	31	10.780 - 11.280
	32	11.770 - 12.270
Cloud Top Altitude	33	13.185 - 13.485
	34	13.485 - 13.785
	35	13.785 - 14.085
	36	14.085 - 14.385

MODIS

- Bands AQUA

Calibration	MYD 01	Level-1A Radiance Counts
	MYD 02	Level-1B Calibrated Geolocated Radiances
	MYD 03	Geolocation Data Set
Atmosphere	MYD 04	Aerosol Product
	MYD 05	Water Vapour
	MYD 06	Cloud Product
	MYD 07	Atmospheric Profiles
	MYD 08	Gridded Atmospheric Product
	MYD 35	Cloud Mask
Land	MYD 09	Surface Reflectance
	MYD 11	Land Surface Temperature & Emissivity
	MYD 12	Land Cover/Change
	MYD 13	Gridded Vegetation Indices
	MYD 14	Thermal Anomalies, Fires & Biomass Burning
	MYD 15	Leaf Area Index & FPAR
	MYD 16	Evapotranspiration
	MYD 17	Net Photosynthesis and Primary Productivity
	MYD 43	Surface Reflectance
	MYD 44	Vegetation Cover Conversion
Cryosphere	MYD 10	Snow Cover
	MYD 29	Sea Ice Cover
Ocean	MYD 18	Normalized Water-leaving Radiance
	MYD 19	Pigment Concentration
	MYD 20	Chlorophyll Fluorescence
	MYD 21	Chlorophyll_a Pigment Concentration

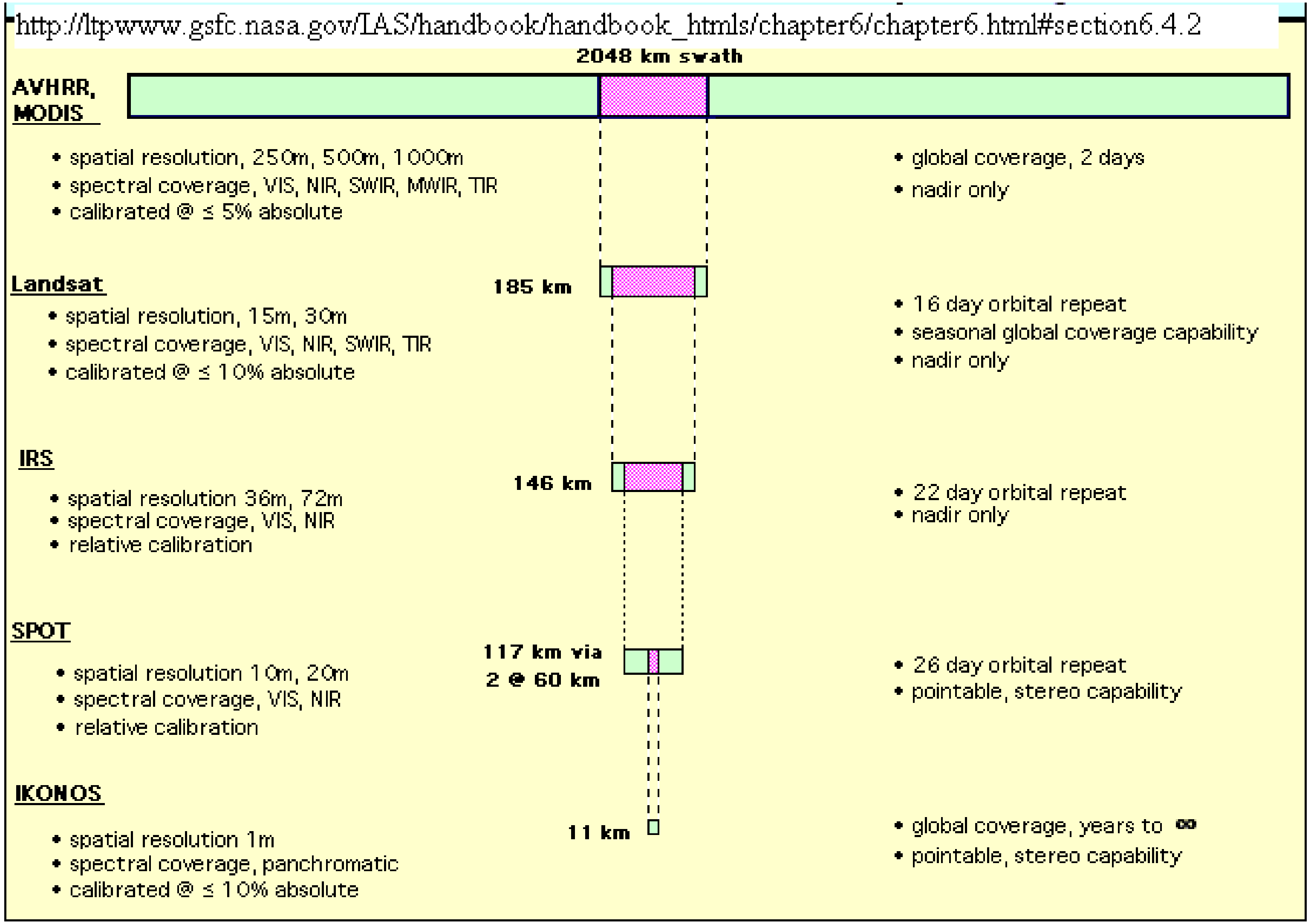
IKONOS

- Comercial satellite
- A series of heliosynchronous, polar, circular orbiting satellites, managed by GeoEye and intended to provide high-resolution commercial imagery.
- The IKONOS-1 satellite failed to launch on 27 April 1999; the IKONOS-2 satellite, at a nominal altitude of 681 km at perigee and 709 km at apogee, was launched on 24 September 1999.
- Main sensor: OSA.

Sensor					
Satellite	Sensor	Bands	Spectral Range	Scene Size	Pixel Res
IKONOS-2	Multi-spectral	1=Blue	455 - 520 μm	11 X 11 km	4 meter
		2=Green	510 - 600 μm		
		3=Red	630 - 700 μm		
		4=NIR	760 - 850 μm		
	Panchromatic	Pan	760 - 850 μm		1 meter

IKONOS

- **OSA**: Optical Sensor Assembly.
- Sensor mainly used to obtain images of high spatial detail and DEM. It allows images to be obtained in the VIS and NIR spectral regions with a spatial resolution at nadir of more than 1 m in the panchromatic band (called PAN) and about 4 m in the multispectral band (called MS).
- Its scans have a radiometric resolution of 11 bits and are distributed with a territorial coverage of 11 km.
- The satellite has pointing capability in all directions, with an observation range of about 820 km. The revisit time is about 3 days.

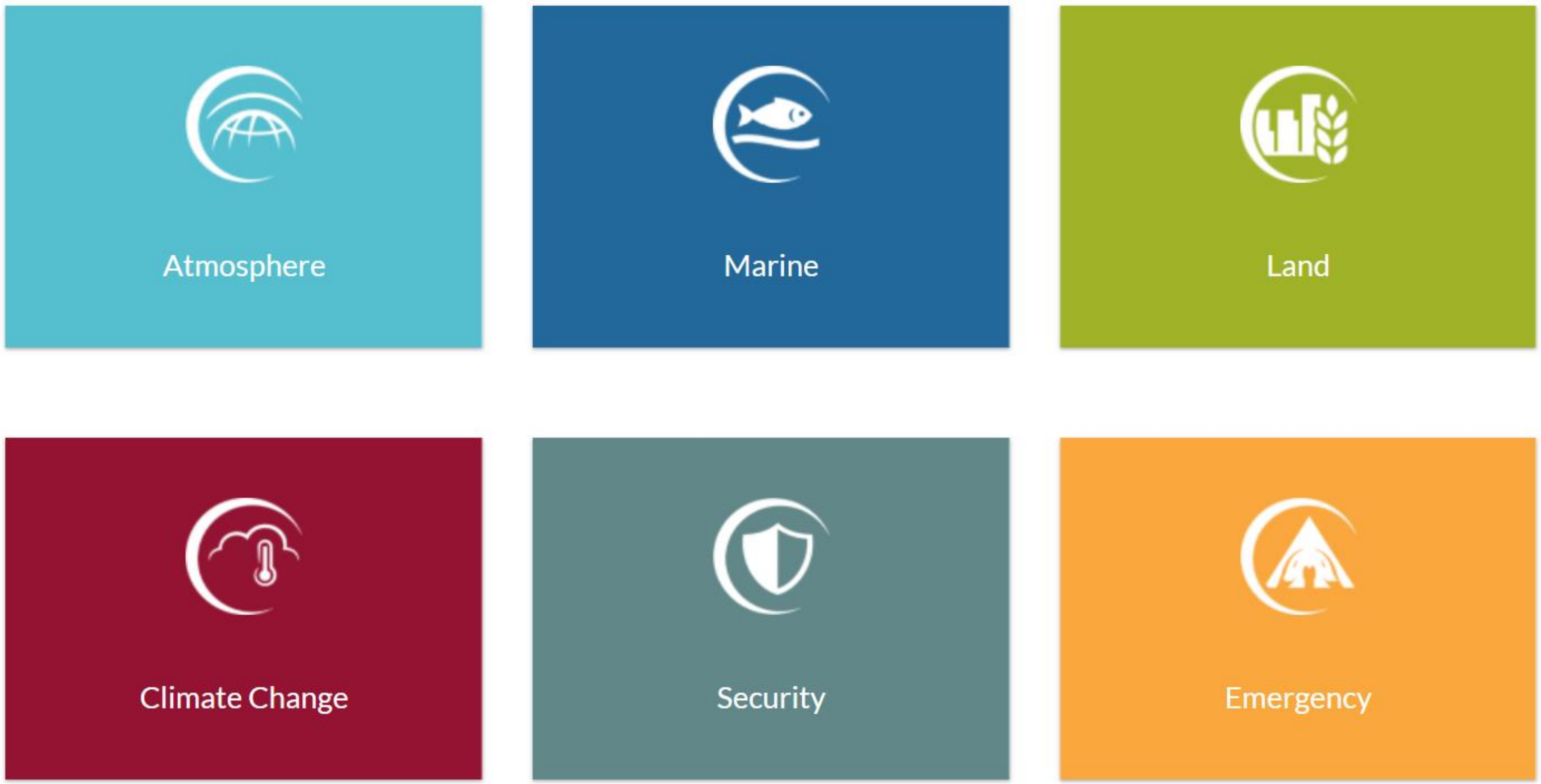


http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_htmls/chapter6/chapter6.html#section6.4.2
2048 km swath
AVHRR, MODIS
• spatial resolution, 250m, 500m, 1000m
• spectral coverage, VIS, NIR, SWIR, MWIR, TIR
• calibrated @ ≤ 5% absolute
• global coverage, 2 days
• nadir only
Landsat
185 km
• spatial resolution, 15m, 30m
• spectral coverage, VIS, NIR, SWIR, TIR
• calibrated @ ≤ 10% absolute
• 16 day orbital repeat
• seasonal global coverage capability
• nadir only
IRS
146 km
• spatial resolution 36m, 72m
• spectral coverage, VIS, NIR
• relative calibration
• 22 day orbital repeat
• nadir only
SPOT
117 km via
2 @ 60 km
• spatial resolution 10m, 20m
• spectral coverage, VIS, NIR
• relative calibration
• 26 day orbital repeat
• pointable, stereo capability
IKONOS
11 km
• spatial resolution 1m
• spectral coverage, panchromatic
• calibrated @ ≤ 10% absolute
• global coverage, years to ∞
• pointable, stereo capability

Sentinels and Copernicus

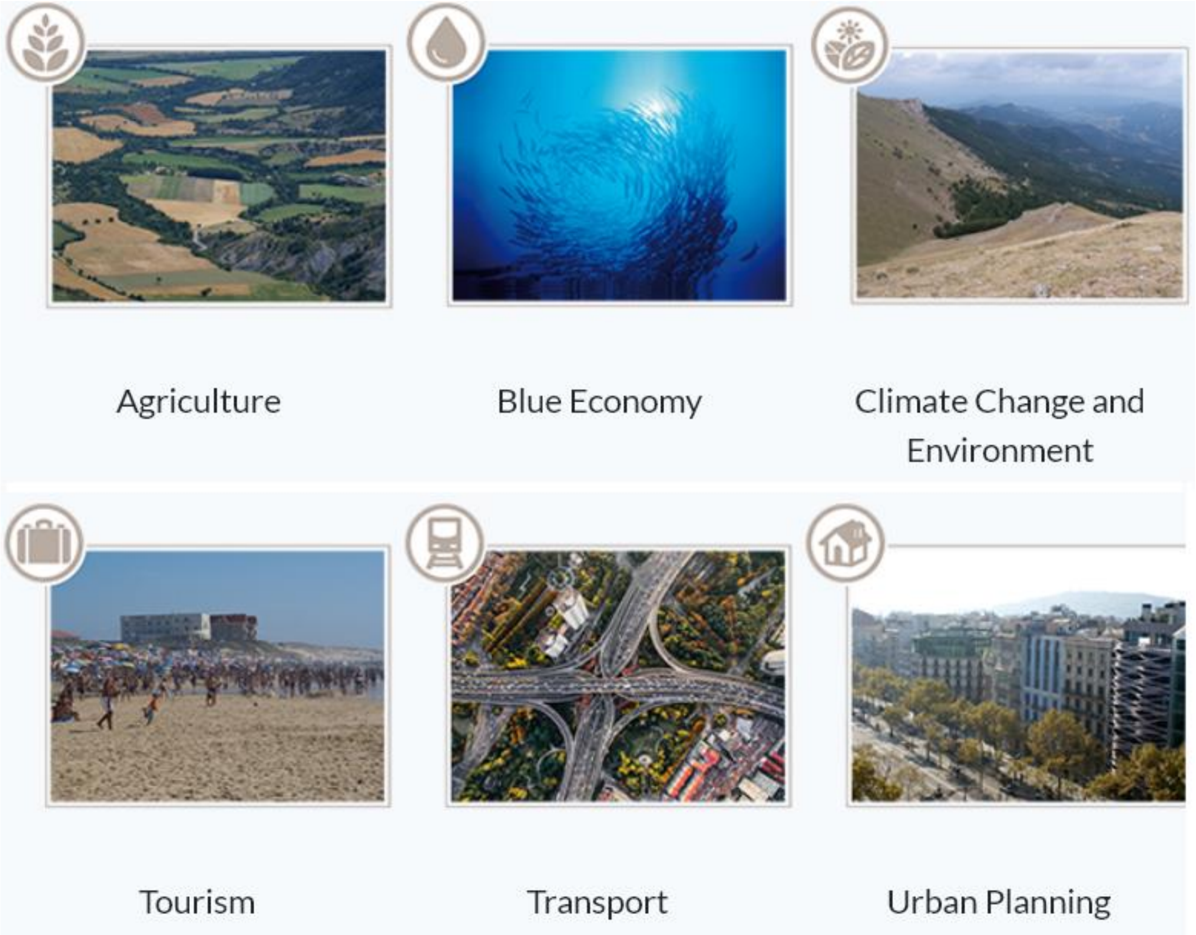
Copernicus: Initiative of the European Commission and ESA to develop a set of services to monitor the state of the environment and its relationship with climate change, and at the same time improve the safety of citizens in case of emergency situations (previously known as GMES).

Copernicus Services



https://www.copernicus.eu/en/copernicus-services

Sectors and Impacts



https://www.copernicus.eu/en/about-copernicus/impact-copernicus

Copernicus - Land

land.copernicus.eu

Portfolio category	Product name	Individual products
Systematic Biophysical Monitoring	Snow and Ice*	Fractional Snow Cover (FSC) | Permanent Snow Line |River/Lake Ice
	High Resolution Phenology*	Various phenological indicators and seasonal trajectories
Land Cover & Land Use Mapping	Corine Land Cover (CLC)	LCLU status and change
	Corine Land Cover plus (CLC+)*	CLC-backbone | CLC-core | CLC+ instance | CLC – legacy
	High Resolution Layers	Imperviousness | Forest | Grassland | Wetness & Water | Small Woody Features
Thematic Hotspot Mapping	Urban Atlas	LCLU status and change
	Riparian Zones	LCLU status and change
	Natura 2000	LCLU status and change
	Coastal Zones*	LCLU status and change
Reference Data	EU-DEM	EU-DEM | Slope | Aspect | Hillshade
	EU-Hydro	Rivers (centreline and outline) | Inland waters Coastline | Drainage network
	Image Mosaics	Very High Resolution (VHR) | High Resolution (HR)
Ground Motion Service*		

Copernicus - Emergency

The **early warning component** of the Copernicus EMS consists of three different systems:

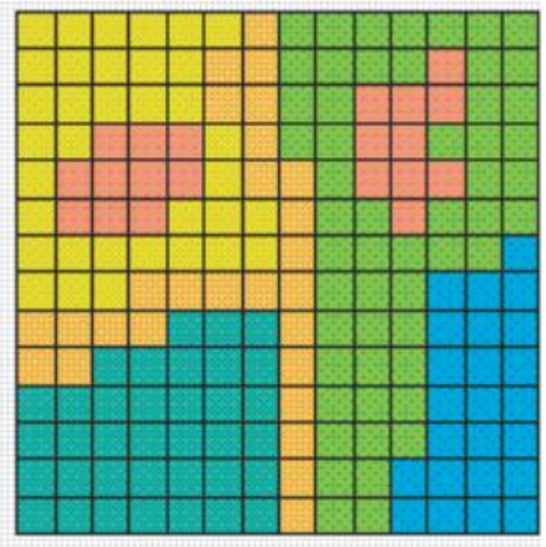
- The European Flood Awareness System (**EFAS**), which provides overviews on ongoing and forecasted floods in Europe up to 10 days in advance.
- The European Forest Fire Information System (**EFFIS**), which provides near real-time and historical information on forest fires and forest fire regimes in the European, Middle Eastern and North African regions.
- The European Drought Observatory (**EDO**), which provides drought-relevant information and early-warnings for Europe.

Data types

CERTH

Raster vs Vector

There are two main type of image files: Raster and Vector. Raster images are pixel-based while vector graphics are based on math-defined.



“raster is faster,

but vector is corrector”

Some Raster Formats

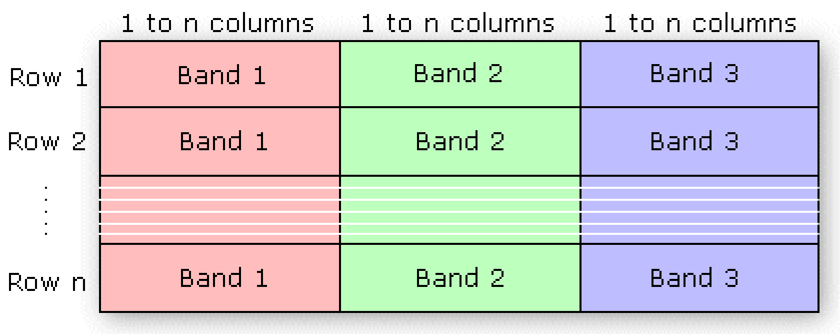
format	ERDAS Imagine (IMG)	ASCII Grid	GeoTIFF	ENVI Raw Raster	Esri Grid	IDRISI Raster	PCIDSK	Enhanced Compression Wavelet	GMLJP2
logo	Im	ASCII	GeoTIFF		-	-	-	Ec	JPEG 2000
file extension	.IMG	.ASC	.GEOTIFF	.BIL .BIP .BSQ	-	.RST .RDC	.PIX	.ECW	.JP2
company	HEXAGON	esri	OGC Making location count.	L3HARRIS	esri	CLARK LABS	PCI GEOMATICS	HEXAGON	OGC Making location count.

compressed

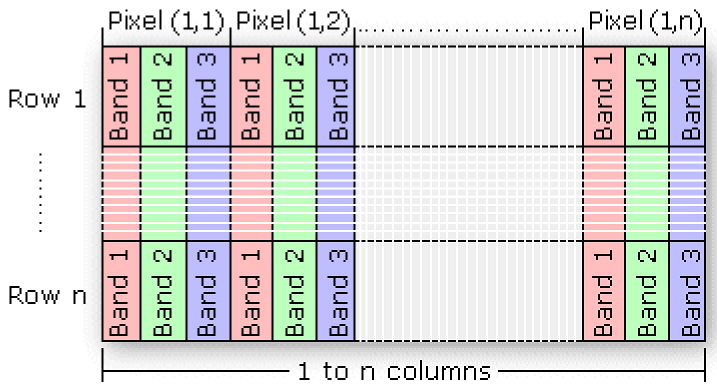
The ENVI image format

The ENVI image format is a flat-binary raster file with an accompanying ASCII header file.

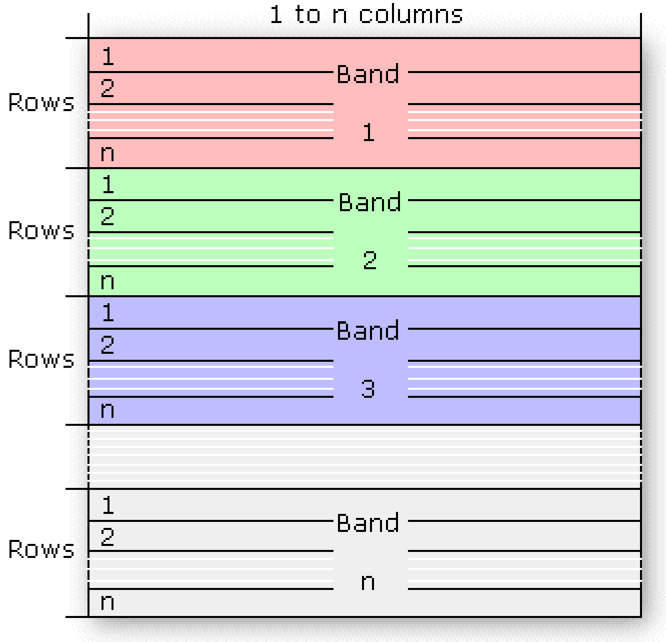
BIL



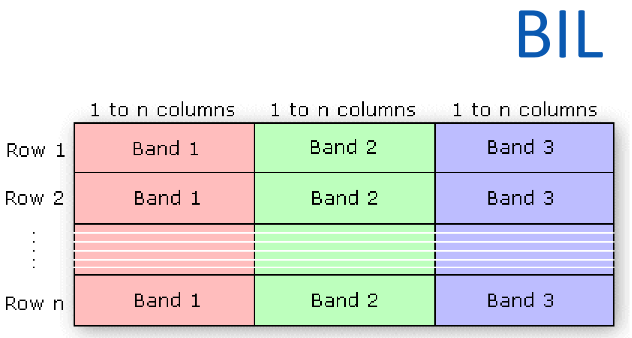
BIP

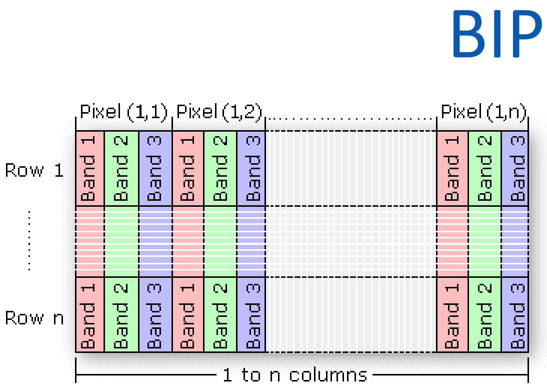


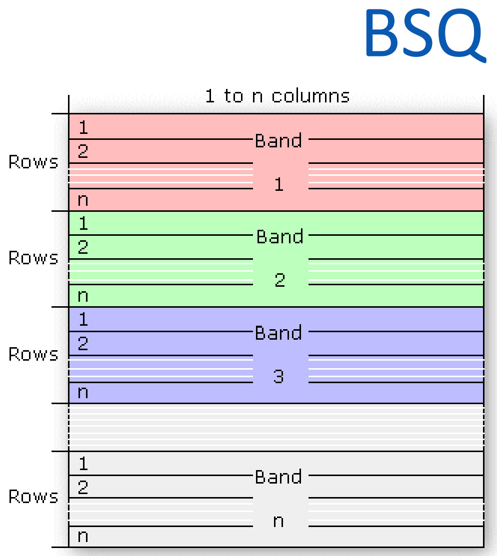
BSQ



The ENVI image format







Band Sequential: BSQ format is the simplest format, where each line of the data is followed immediately by the next line in the same spectral band. This format is optimal for spatial (x,y) access of any part of a single spectral band.

Band-interleaved-by-pixel: BIP format stores the first pixel for all bands in sequential order, followed by the second pixel for all bands, followed by the third pixel for all bands, and so forth, interleaved up to the number of pixels. This format provides optimum performance for spectral (z) access of the image data.

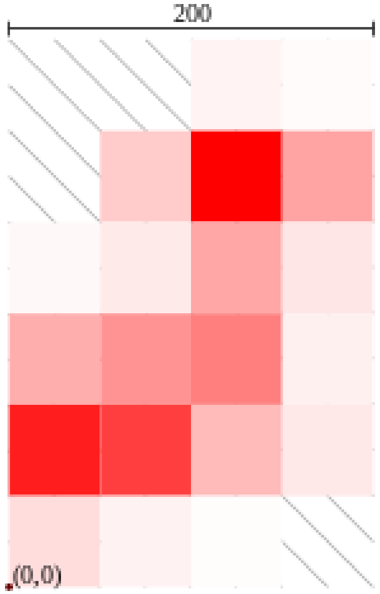
Band-interleaved-by-line: BIL format stores the first line of the first band, followed by the first line of the second band, followed by the first line of the third band, interleaved up to the number of bands. Subsequent lines for each band are interleaved in similar fashion. This format provides a compromise in performance between spatial and spectral processing and is the recommended file format for most ENVI processing tasks.

ASCII Grid

An Esri grid is a raster GIS file format developed by Esri, which has two formats:

- A proprietary binary format, also known as an ARC/INFO GRID, ARC GRID and many other variations
- A non-proprietary ASCII format, also known as an ARC/INFO ASCII GRID

Grid image



Values

	25	75	125	175
275	NA	NA	5	2
225	NA	20	100	36
175	3	8	35	10
125	32	42	50	6
75	88	75	27	9
25	13	5	1	NA

ASCII grid format

```
ncols         4
nrows         6
xllcorner     0.0
yllcorner     0.0
cellsize      50.0
NODATA_value  -9999
-9999 -9999 5 2
-9999 20 100 36
3 8 35 10
32 42 50 6
88 75 27 9
13 5 1 -9999
```

GeoTIFF

GeoTIFF is a public domain metadata standard which allows georeferencing information to be embedded within a TIFF file.

- 1994 - SPOT Image Corp proposes a GeoTIFF structure that was limited to Universal Transverse Mercator
- 1997 - The GeoTIFF format was originally created by Dr. Niles Ritter while he was working at the NASA Jet Propulsion Laboratory
- 2000 - GeoTIFF Format Specification Revision 1.0

- Ritter, N., & Ruth, M. (1997). The GeoTiff data interchange standard for raster geographic images. In International Journal of Remote Sensing (Vol. 18, Issue 7, pp. 1637–1647). Informa UK Limited. https://doi.org/10.1080/014311697218340

Geotiff metadata

A GeoTIFF file extension contains geographic metadata that describes the actual location in space that each pixel in an image represents. In creating a GeoTIFF file, spatial information is included in the .tif file as embedded tags, which can include raster image metadata such as:

- horizontal and vertical datums
- spatial extent, i.e. the area that the dataset covers
- the coordinate reference system (CRS) used to store the data
- spatial resolution, measured in the number of independent pixel values per unit length
- the number of layers in the .tif file
- ellipsoids and geoids - estimated models of the Earth's shape
- mathematical rules for map projection to transform data for a three-dimensional space into a two-dimensional display

- Ritter, N., & Ruth, M. (1997). The GeoTiff data interchange standard for raster geographic images. In International Journal of Remote Sensing (Vol. 18, Issue 7, pp. 1637–1647). Informa UK Limited. https://doi.org/10.1080/014311697218340

1.1. GeoTIFF : Limitations

- not suitable for storing complex multi-dimensional data structures nor for storing vector data with many attributes or topology information.
- the principal disadvantage of TIFF is file size.

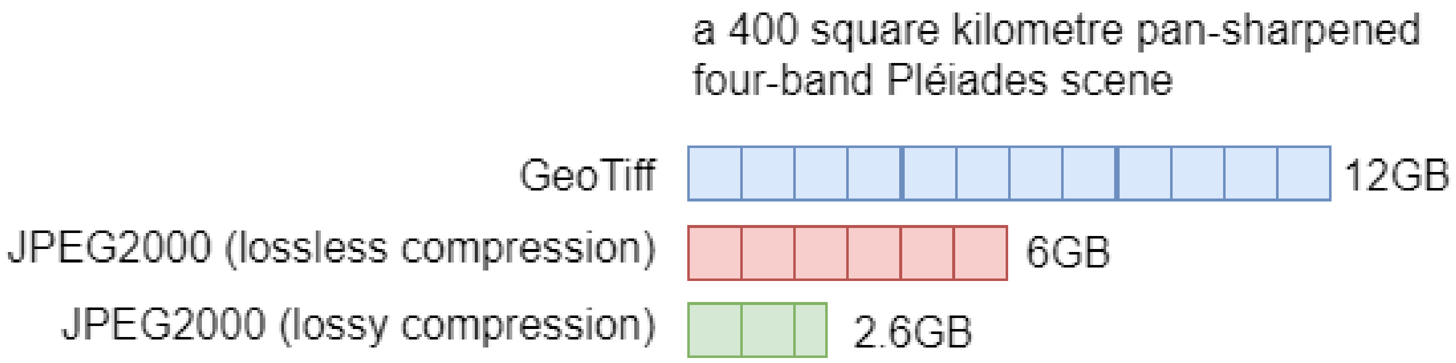
JPEG2000

- JPEG 2000 is an image compression and coding system format to the ISO/CEI 15444-1 standard that is ideally suited to handling satellite images.
- It enables images to be viewed in variable compression modes, making it popular with users looking for ever increased precision, resolution and information content in geospatial imagery, as well as for faster access to data.

- JPEG 2000 Whitepaper: Overview and benefits for modern geospatial imagery applications https://www.intelligence-airbusds.com/files/pmedia/public/r15186_9_jpeg2000_astrium_exelis.pdf

JPEG2000 – Advantages (1/2)

- Data Storage takes up less disk space
- Supports both reversible (lossless) and irreversible (lossy) compression



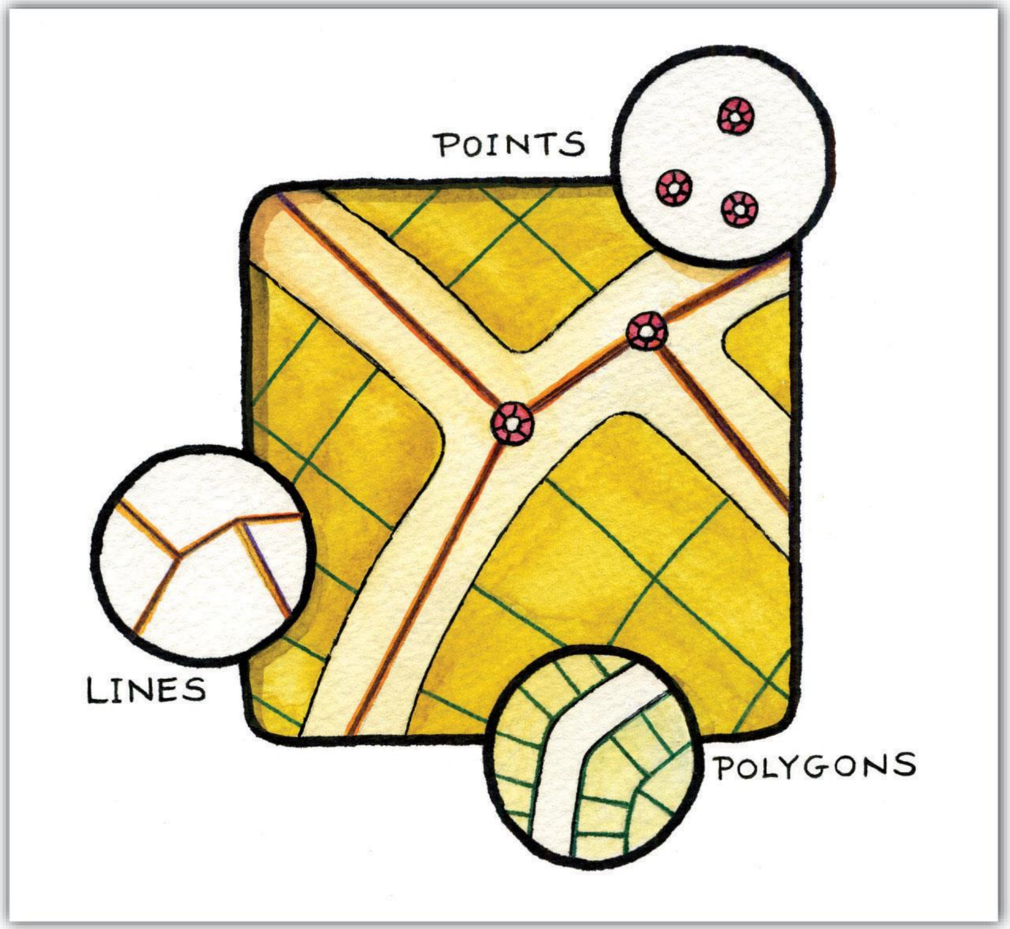
- JPEG 2000 Whitepaper: Overview and benefits for modern geospatial imagery applications https://www.intelligence-airbusds.com/files/pmedia/public/r15186_9_jpeg2000_astrium_exelis.pdf

JPEG2000 – Advantages (2/2)

- Downloading/uncompressing is much faster
- It can handle large images, i.e., those that are greater than 64k x 64k pixels, also natural and computer-generated imagery, without tiling.
- No limit in the amount of private or special-purpose information in the metadata.

- JPEG 2000 Whitepaper: Overview and benefits for modern geospatial imagery applications https://www.intelligence-airbusds.com/files/pmedia/public/r15186_9_jpeg2000_astrium_exelis.pdf

Vector Formats



Vectors are built from mathematically defined shapes like lines and curves.

Some Vector Formats

logo	SHP	KML	GEOJSON	GML	GPX	OSM
file extension	.SHP .DBF .SHX	.KML .KMZ	.GEOJSON	.GML	.GPX	.OSM
company	esri	OGC Making location count.	IETF	OGC Making location count.		OPEN STREET MAP FOUNDATION
based-upon		XML	JSON	XML	XML	XML
	proprietary but open		open standard			

Vector formats for remote sensing

- Usually secondary products
- Useful for masking satellite imagery using shapefiles

Containers

In computer science, a container is a class or a data structure whose instances are collections of other objects. In other words, they store objects in an organized way that follows specific access rules.

	netCDF	HDF	GeoPackage	CDB
file extension	.NC	.HDF	.GRIB	
company	unidata	The HDF Group		
OGC compliance	✓	✓	✓	✓

NetCDF (Network Common Data Form)

- a set of software libraries and machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data.
- a community standard for sharing scientific data.

- Rew, R., Davis, G., Emmerson, S., Cormack, C., Caron, J., Pincus, R., Hartnett, E., Heimbigner, D., Appel, L., & Fisher, W. (1989). Unidata NetCDF. UCAR/NCAR - Unidata. https://doi.org/10.5065/D6H70CW6

netCDF data attributes

- Self-Describing: A netCDF file includes information about the data it contains.
- Portable: A netCDF file can be accessed by computers with different ways of storing integers, characters, and floating-point numbers.
- Scalable: Small subsets of large datasets in various formats may be accessed efficiently through netCDF interfaces, even from remote servers.
- Appendable: Data may be appended to a properly structured netCDF file without copying the dataset or redefining its structure.
- Sharable: One writer and multiple readers may simultaneously access the same netCDF file.
- Archivable: Access to all earlier forms of netCDF data will be supported by current and future versions of the software.

- Rew, R., Davis, G., Emmerson, S., Cormack, C., Caron, J., Pincus, R., Hartnett, E., Heimbigner, D., Appel, L., & Fisher, W. (1989). Unidata NetCDF. UCAR/NCAR - Unidata. https://doi.org/10.5065/D6H70CW6

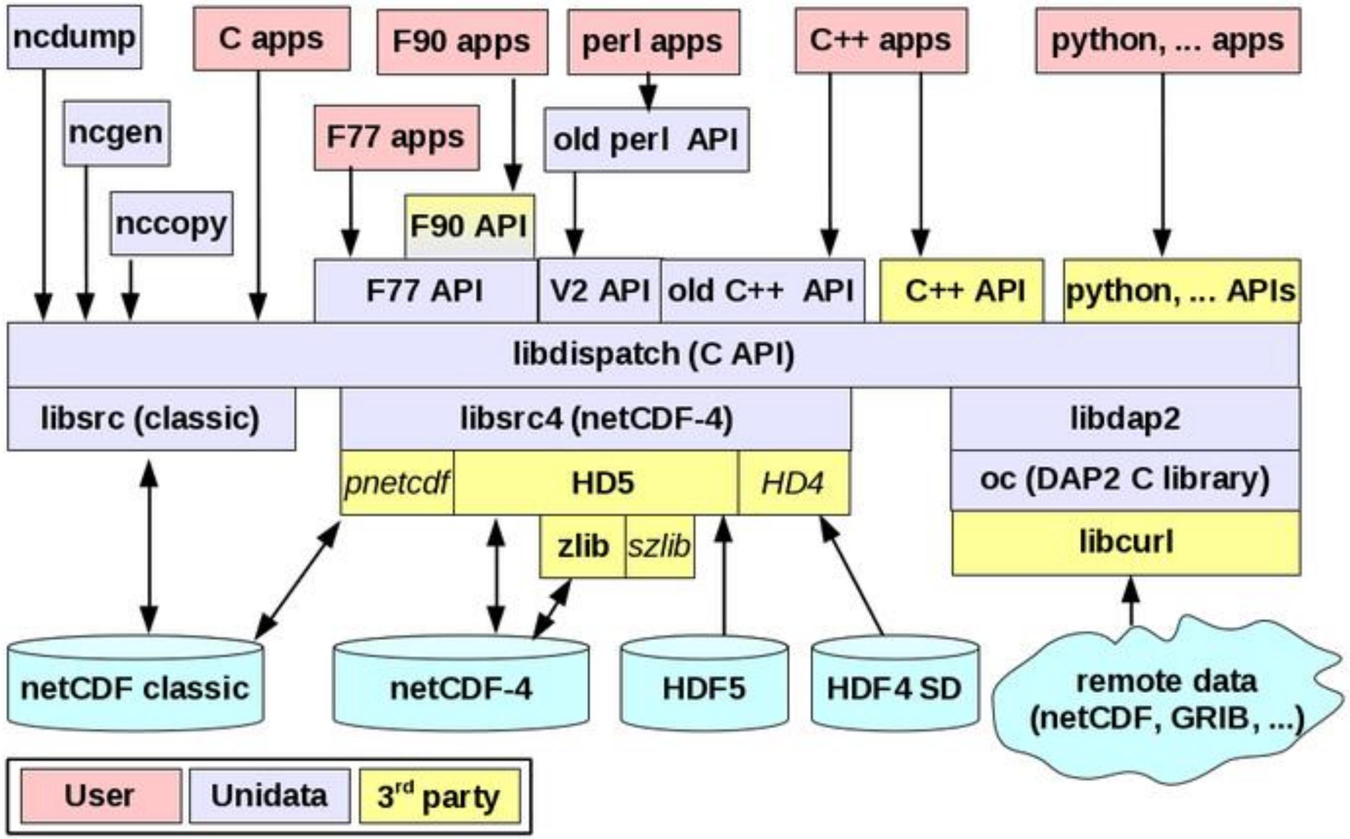
The netCDF File Format

As of January 2012, there are four variants of the format.

- NetCDF Classic Format (CDF-1)
- NetCDF 64-bit Offset Format (CDF-2)
- NetCDF 64-bit Data Format (CDF-5)
- NetCDF-4 Format

The first two, known as Classic and 64-bit Offset, are nearly identical and together are often referred to as netCDF-3.

NetCDF Library Architecture



Read More: https://www.unidata.ucar.edu/software/netcdf/workshops/most-recent/architecture/Layers.html

Example of NetCDF Usage

DLR

The German Aerospace Agency (DLR), located in Munich, are using netcdf-4 / CF standards for the provision of L2 data for S5p mission including L2 products such as Sulfur Dioxide, Ozone, Formaldehyde and Clouds

Further reading suggestions for NetCDF

- Rew, R. K., G. P. Davis, S. Emmerson, and H. Davies, NetCDF User's Guide for C, An Interface for Data Access, Version 3, April 1997.
- Brown, S. A, M. Folk, G. Goucher, and R. Rew, "Software for Portable Scientific Data Management," Computers in Physics, American Institute of Physics, Vol. 7, No. 3, May/June 1993, pp. 304-308.
- Fulker, D. W., "Unidata Strawman for Storing Earth-Referencing Data," Seventh International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, New Orleans, La., American Meteorology Society, January 1991.
- Jenter, H. L. and R. P. Signell, 1992. "[NetCDF: A Freely-Available Software-Solution to Data-Access Problems for Numerical Modelers](http://www.unidata.ucar.edu/software/netcdf/papers/jenter_signell_92.pdf)". Proceedings of the American Society of Civil Engineers Conference on Estuarine and Coastal Modeling. Tampa, Florida.
- Kuehn, J.A., "Faster Libraries for Creating Network-Portable Self-Describing Datasets", Proceedings of the 37th Cray User Group Meeting, (Barcelona, Spain, March 1996), Cray User Group, Inc.
- Rew, R. K. and G. P. Davis, "NetCDF: An Interface for Scientific Data Access," IEEE Computer Graphics and Applications, Vol. 10, No. 4, pp. 76-82, July 1990.
- Rew, R. K. and G. P. Davis, "The Unidata netCDF: Software for Scientific Data Access," Sixth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, Anaheim, California, American Meteorology Society, pp. 33-40, February 1990.
- Rew, R. K. and G. P. Davis, " [Unidata's netCDF Interface for Data Access: Status and Plans](/netcdf/ams97.html)," Thirteenth International Conference on Interactive Information and Processing Systems for Meteorology, Oceanography, and Hydrology, Anaheim, California, American Meteorology Society, February 1997.

An upcoming popular format

Cloud Optimized GeoTIFF

A Cloud Optimized GeoTIFF (COG) is a regular GeoTIFF file, aimed at being hosted on a HTTP file server, with an internal organization that enables more efficient workflows on the cloud. It does this by leveraging the ability of clients issuing HTTP GET range requests to ask for just the parts of a file they need.

Cloud Optimized GeoTIFF

Cloud Optimized GeoTIFF relies on two complementary pieces of technology.

- The first is the ability of a GeoTIFF to not only store the raw pixels of the image, but to also organize those pixels in particular ways.
- The second is HTTP GET range requests, that let clients ask for just the portions of a file that they need. Together these enable fully online processing of data by COG-aware clients, as they can stream the right parts of the GeoTIFF as they need it, instead of having to download the whole file.

Data Distribution

The INSPIRE Directive

an EU initiative to establish an infrastructure for spatial information in Europe that is geared to help to make spatial or geographical information more accessible and interoperable for a wide range of purposes supporting sustainable development

- https://inspire.ec.europa.eu/inspire-directive/2

The need for interoperability (1/2)

The **2010 eruptions of Eyjafjallajökull** were a period of volcanic events at Eyjafjallajökull in Iceland which highlighted the importance of interoperability

The Ash cloud billowing out of Eyjafjallajökull in southern Iceland, April 16th 2020 (Source: Encylopedia Britanica, Brynjar Gauti/AP)

Volcanoes and glaciers of Iceland (Source: Encyclopedia Britanica)

The need for interoperability (2/2)

- The ash cloud from the eruption of Eyjafjallajökull shut down the European airspace
- Several neighboring countries needed data on air pollution and air quality. This data had to be comparable across borders for decision makers in the health and transport domain.

Interoperability addresses this issue

Organizations providing Remote Sensing data

The European Space Agency (ESA) is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world.

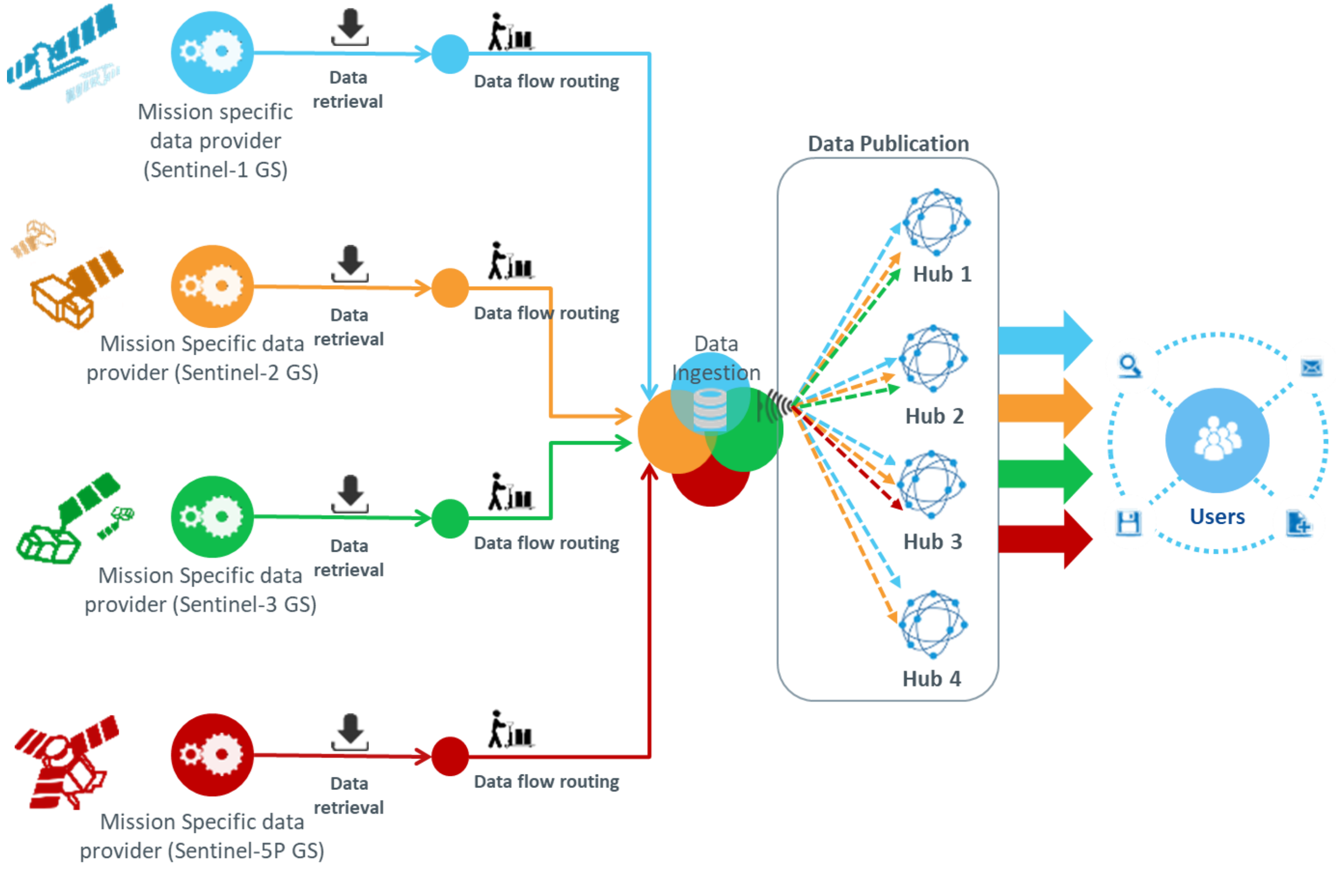
The National Aeronautics and Space Administration is an independent agency of the U.S. federal government responsible for the civilian space program, as well as aeronautics and space research.

The National Oceanic and Atmospheric Administration is an American scientific and regulatory agency within the United States Department of Commerce that forecasts weather, monitors oceanic and atmospheric conditions, charts the seas, conducts deep sea exploration, and manages fishing and protection of marine mammals and endangered species in the U.S. exclusive economic zone.

The United States Geological Survey, abbreviated USGS and formerly simply known as the Geological Survey, is a scientific agency of the United States government. The scientists of the USGS study the landscape of the United States, its natural resources, and the natural hazards that threaten it.

Copernicus Sentinel Data Access System Model

The Data Access System automatically retrieves user-level data from ESA's Sentinel ground segments and publishes them online, on a series of dissemination points known as hubs. Accessing these hubs, users are able to explore the data collections and download user-level data, either through an interactive graphical web interface (GUI) or automatically, using a scripting interface (API).



- Copernicus Sentinel Data Access Annual Report 2020. https://sentinels.copernicus.eu/web/sentinel/-/copernicus-sentinel-data-access-annual-report-2020

Copernicus Sentinel Data Access System Model

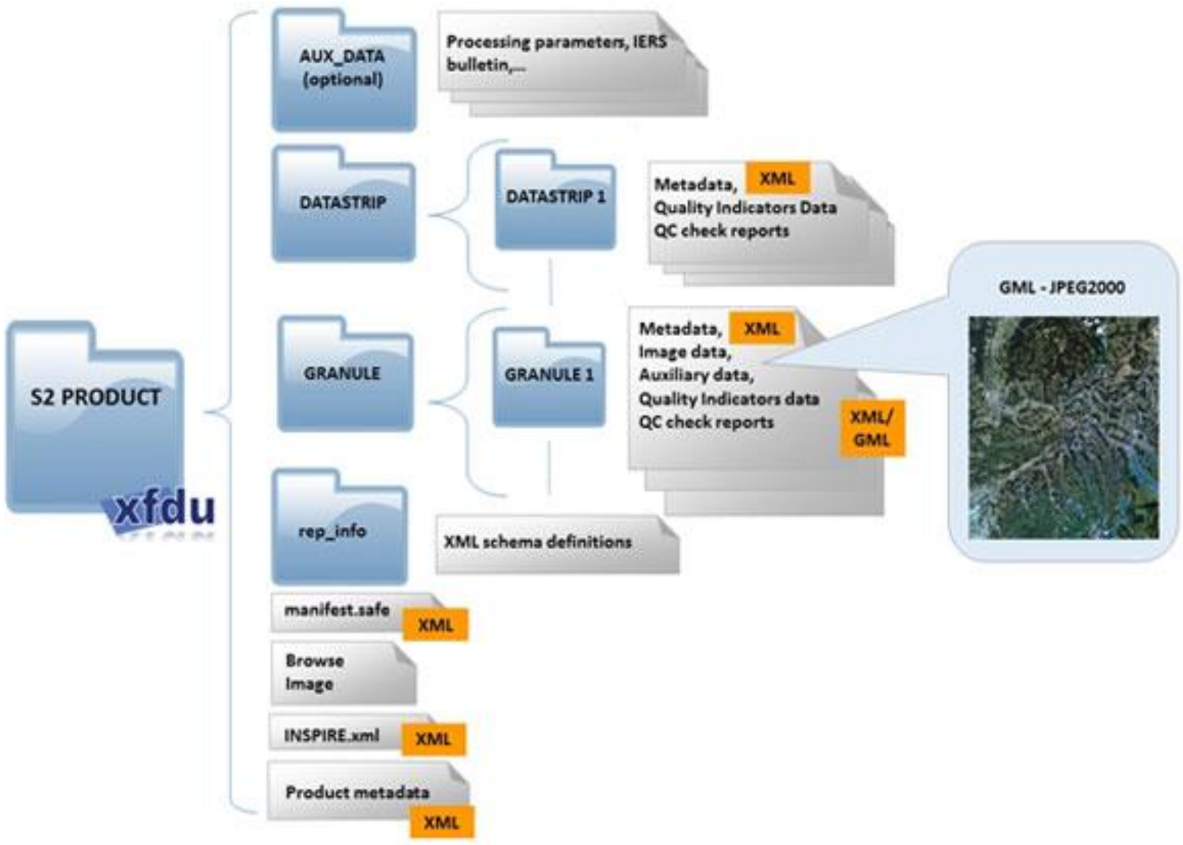
- The **Copernicus Open Access Hub** offers to all users free, full and open access to Copernicus Sentinel data on the basis of self registration.
- The **Copernicus Services Hub** guarantees free and full access to Copernicus Sentinel data for all Copernicus Services and EU institutions.
- The **Collaborative Hub** is open to all Copernicus Participating States, following signature of a CollGS agreement with ESA or an internal agreement with the European Commission.
- The **International Hub** is open to international partners, following signature of a cooperation agreement with the European Commission and a technical operating arrangement with ESA.

- Copernicus Sentinel Data Access Annual Report 2020. https://sentinels.copernicus.eu/web/sentinel/-/copernicus-sentinel-data-access-annual-report-2020

Sentinel 2 Data Structure

A SENTINEL-2 product refers to a directory folder that contains a collection of information. It includes:

- a manifest.safe file which holds the general product information in XML
- a preview image in JPEG2000 format
- subfolders for measurement datasets including image data (granules/tiles) in GML-JPEG2000 format
- subfolders for datastrip level information
- a subfolder with auxiliary data (e.g. International Earth Rotation & Reference Systems (IERS) bulletin)
- HTML previews



- Copernicus Sentinel Data Access Annual Report 2020. https://sentinels.copernicus.eu/web/sentinel/-/copernicus-sentinel-data-access-annual-report-2020

FAQs

- How is GeoTIFF different from TIFF?

"GeoTIFF" refers to TIFF files which have geographic (or cartographic) data embedded as tags within the TIFF file. The geographic data can then be used to position the image in the correct location and geometry on the screen of a geographic information display. GeoTIFF is a metadata format, which provides geographic information to associate with the image data. But the TIFF file structure allows both the metadata and the image data to be encoded into the same file. GeoTIFF makes use of a public tag structure which is platform interoperable between any and all GeoTIFF-savvy readers. Any GIS, CAD, Image Processing, Desktop Mapping and any other types of systems using geographic images can read any GeoTIFF files created on any system to the GeoTIFF specification.

- Can systems that don't use geography read a GeoTIFF image?

Many such image "visualization" systems do not use geography as a basis for placement of their images. These systems are all able to view a GeoTIFF image just as though there were no geographic information in the TIFF file. To non-GeoTIFF-savvy readers, the GeoTIFF image should look and behave like any other TIFF image.

FAQs

- What is the connection between netCDF and CDF?

CDF was developed at the NASA Space Science Data Center at Goddard, and is freely available. It was originally a VMS FORTRAN interface for scientific data access. Unidata reimplemented the library from scratch to use XDR for a machine-independent representation, designed the CDL (network Common Data form Language) text representation for netCDF data, and added aggregate data access, a single-file implementation, named dimensions, and variable-specific attributes. NetCDF and CDF have evolved independently. CDF now supports many of the same features as netCDF (aggregate data access, XDR representation, single-file representation, variable-specific attributes), but some differences remain (netCDF doesn't support native-mode representation, CDF doesn't support named dimensions). There is no compatibility between data in CDF and netCDF form, but NASA makes available some translators between various scientific data formats. For a more detailed description of differences between CDF and netCDF, see the CDF FAQ.

- Can anyone have access to Copernicus data and information?

Although primarily designed for public policy-makers and public bodies responsible for environmental and security matters, data and information provided by Copernicus are not limited to these users. Any public or private organisation, and more generally any individual can access and exploit Copernicus data and information on a free, full and open basis. The only exceptions are the specific situations where security is at stake. In such cases, access limitation may exist.