

Materiale didattico per il corso:

- 059AR - TELERILEVAMENTO PER LO STUDIO DEL TERRITORIO - REMOTE SENSING FOR TERRITORIAL STUDY
- Docente: Andrea Favretto

afavretto@units.it

Parte terza

Telerilevamento come strumento di controllo militare

Il Telerilevamento, come molte altre tecnologie/scienze oggi molto diffuse ad uso civile, deve molto alla guerra (calda e fredda).

Nel 1967 il Presidente americano Lyndon Johnson aveva affermato di aver proficuamente speso circa 40 miliardi di dollari nel cosiddetto programma spaziale, grazie al quale gli USA erano al tempo in grado di conoscere la potenza missilistica del nemico.

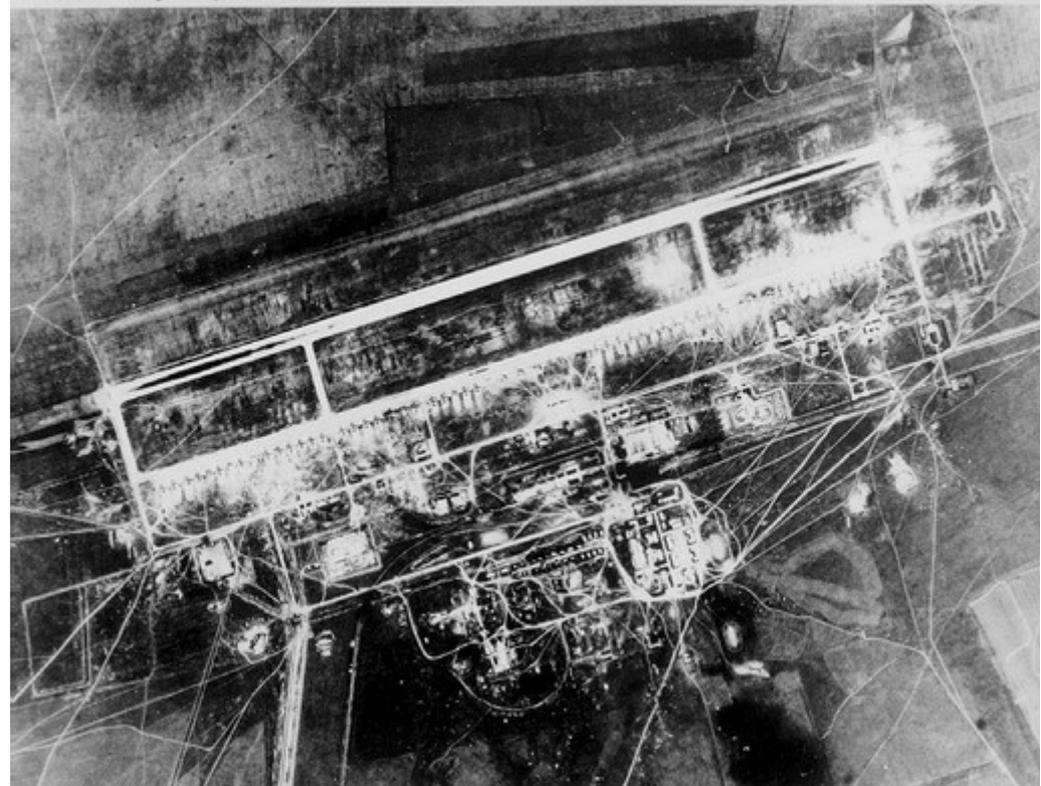
Progetto Corona: è stato il primo satellite americano per sorvegliare i sovietici. Il primo volo del satellite fu il 18 agosto 1960. Furono ripresi più di 4 milioni di km quadrati del territorio sovietico (914 metri di pellicola).



Nel 1960 le immagini avevano una risoluzione spaziale di 40 piedi (circa 12 metri)

Nel 1972 arrivarono a 4,4 - 6 piedi (1,3 – 1,8 metri)

Soviet Long-Range Aviation Airfield, 20 August 1966

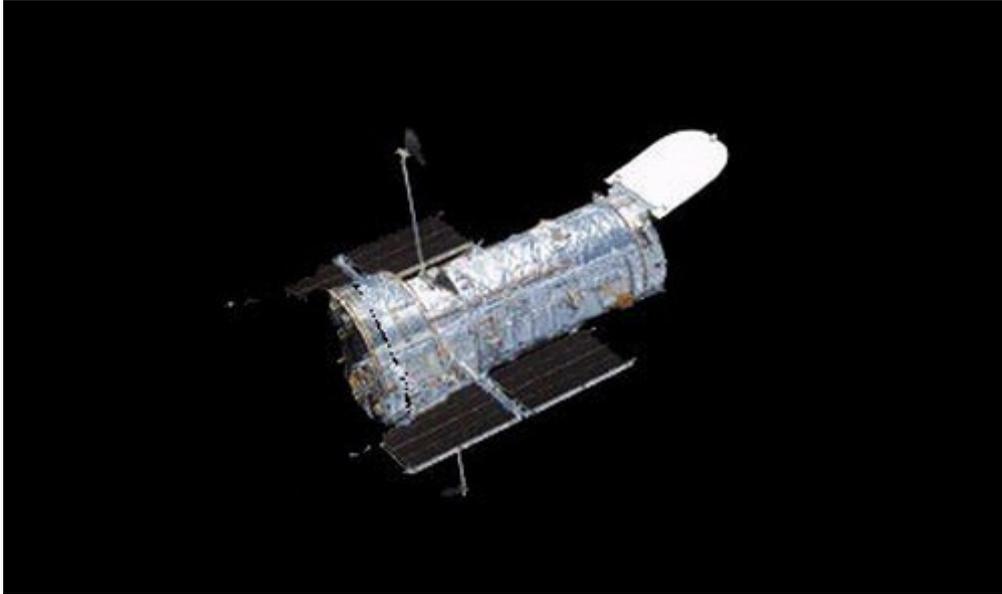


La Guerra del golfo del 1991 fu addirittura denominata “hyperwar”, a causa della grande influenza del Telerilevamento da satellite e aereo su moltissime delle decisioni strategiche prese dalle forze armate americane ed alleate.

kuwait_oil_fires

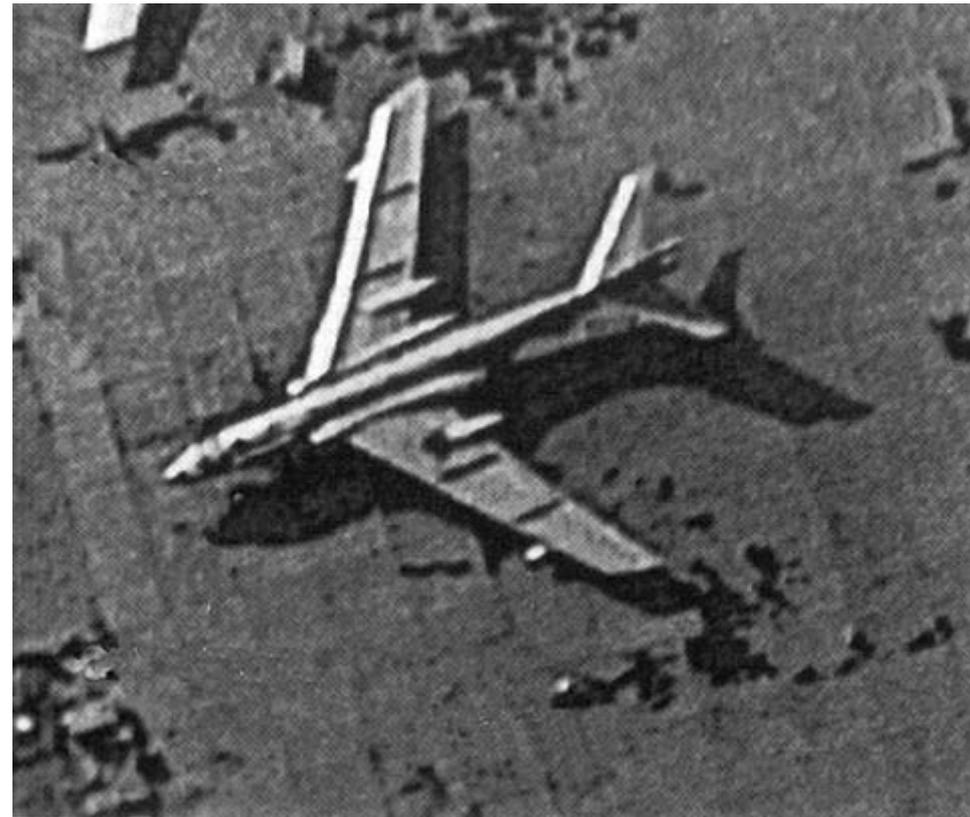


Il Telerilevamento ha continuato ad essere massivamente impiegato a fini strategici (oggi i satelliti militari KH – KeyHole class – sono addirittura equipaggiati con un telescopio Hubble e permettono di acquisire immagini radar ad una risoluzione spaziale di 12 centimetri).



Highly accurate model of a top secret KH-11 digital imaging recon satellite in space illustrates the "Stubby Hubble" KH-11 characteristic with a shorter telescope tube and shorter focal length

An image of a Communist Chinese jet bomber taken by an NRO KH-11 spacecraft flying at more than 200 miles altitude



Telerilevamento ad usi civili per il controllo della superficie terrestre

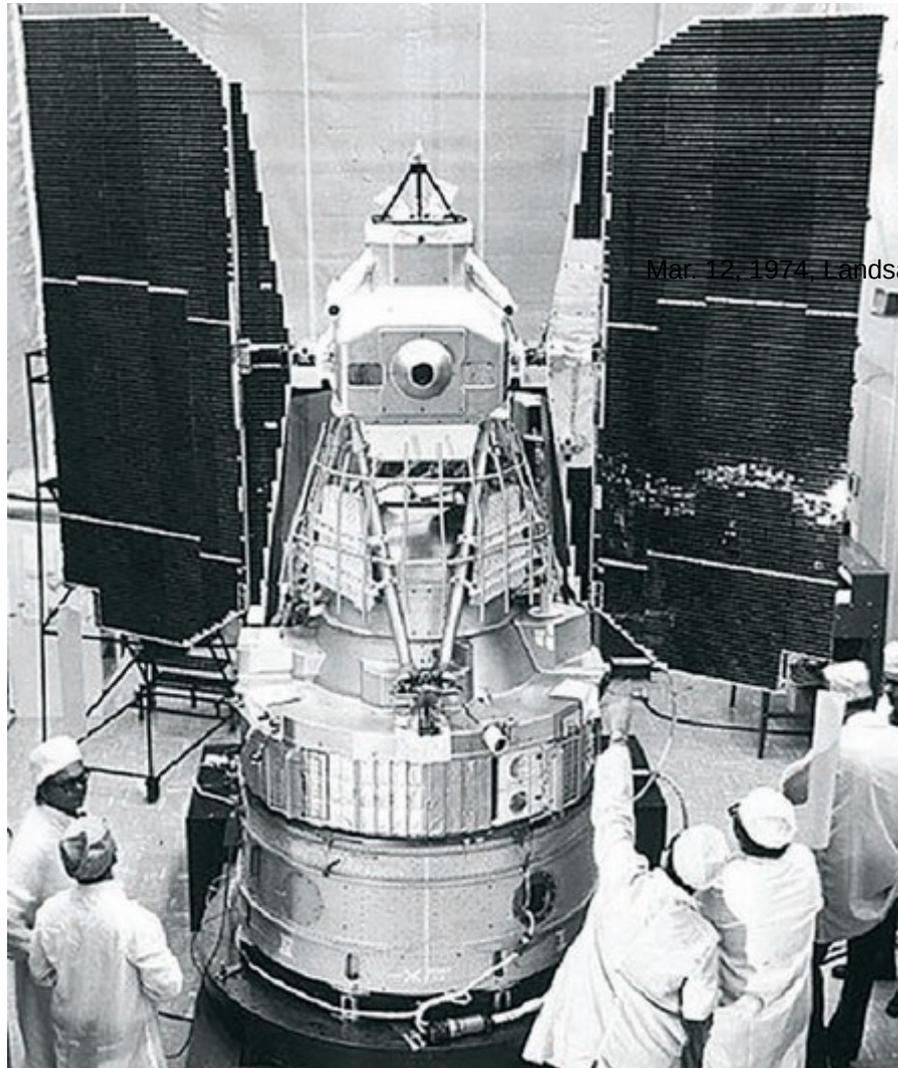
Sensori a media risoluzione spaziale distribuiti gratuitamente

Cronologicamente, possiamo far risalire agli anni '70 del secolo scorso la costruzione dei primi sistemi per l'acquisizione di dati ambientali attraverso satelliti artificiali senza equipaggio.

Nel 1972 fu infatti lanciato in orbita ERTS-1 (Earth Resources Technology Satellite), successivamente rinominato Landsat -1.



Mar. 12, 1974, Landsat 1
Dallas/Fort Worth, Texas



Mar. 12, 1974, Landsat 1 (path/row 29/37) — Dallas/Fort Worth, TX



Il programma Landsat

Dal suo lontano inizio, il programma Landsat ha consentito l'acquisizione di scene a quasi tutte le latitudini (a parte quelle polari più elevate).

Degli otto lanci, dal 1972 ad oggi, solo quello di Landsat 6 (ottobre 1993), è fallito (il satellite non è riuscito a raggiungere l'orbita prevista).

Il programma ha consentito negli anni l'allestimento della più grande biblioteca di immagini multispettrali a media risoluzione spaziale del pianeta Terra.

I numeri dell'archivio Landsat sono infatti assolutamente notevoli: si tratta di ben 5,5 milioni di immagini al Gennaio 2015.

Tutte le immagini sono attualmente gestite da NASA, l'ente aerospaziale americano, in collaborazione con USGS (U.S. Geological Survey), l'ente cartografico americano.

L'intero archivio è stato reso gratuitamente disponibile in rete dal Dicembre del 2008.



<http://landsat.usgs.gov/>



Caratteristiche tecniche dei sensori: MSS

Multispectral Scanner (MSS)	Landsat 1-3	Landsat 4-5	Wavelength (micrometers)	Resolution (meters)
	Band 4	Band 1	0.5-0.6	60*
	Band 5	Band 2	0.6-0.7	60*
	Band 6	Band 3	0.7-0.8	60*
	Band 7	Band 4	0.8-1.1	60*

Landsat Multi Spectral Scanner (MSS)

Landsat MSS 1, 2,3 Spectral Bands	Landsat MSS 4,5 Spectral Bands	Wavelength	Useful for mapping
Band 4 - green	Band 1 - green	0.5 - 0.6	Sediment-laden water, delineates areas of shallow water
Band 5 - red	Band 2 - red	0.6 - 0.7	Cultural features
Band 6 - Near Infrared	Band 3 - Near Infrared	0.7 - 0.8	Vegetation boundary between land and water, and landforms
Band 7 - Near Infrared	Band 4 - Near Infrared	0.8 - 1.1	Penetrates atmospheric haze best, emphasizes vegetation, bounda

Caratteristiche tecniche dei sensori: TM, ETM+

Thematic Mapper (TM)

Landsat 4-5	Wavelength (micrometers)	Resolution (meters)
Band 1	0.45-0.52	30
Band 2	0.52-0.60	30
Band 3	0.63-0.69	30
Band 4	0.76-0.90	30
Band 5	1.55-1.75	30
Band 6	10.40-12.50	120* (30)

Enhanced Thematic Mapper Plus (ETM+)

Landsat 7	Wavelength (micrometers)	Resolution (meters)
Band 1	0.45-0.52	30
Band 2	0.52-0.60	30
Band 3	0.63-0.69	30
Band 4	0.77-0.90	30
Band 5	1.55-1.75	30
Band 6	10.40-12.50	60 * (30)
Band 7	2.09-2.35	30
Band 8	.52-.90	15

Landsat 4-5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+)

Band	Wavelength	Useful for mapping
Band 1 - blue	0.45 - 0.52	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
Band 2 - green	0.52 - 0.60	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 3 - red	0.63 - 0.69	Discriminates vegetation slopes
Band 4 - Near Infrared	0.77 - 0.90	Emphasizes biomass content and shorelines
Band 5 - Short-wave Infrared	1.55 - 1.75	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 6 - Thermal Infrared	10.40 - 12.50	Thermal mapping and estimated soil moisture
Band 7 - Short-wave Infrared	2.09 - 2.35	Hydrothermally altered rocks associated with mineral deposits
Band 8 - Panchromatic (Landsat 7 only)	0.52 - 0.90	15 meter resolution, sharper image definition

Caratteristiche tecniche dei sensori: OLI & TIRS

**Landsat 8
Operational
Land Imager
(OLI)
and
Thermal
Infrared
Sensor
(TIRS)**

**Launched
February 11, 2013**

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Coastal aerosol	0.43 - 0.45	30
Band 2 - Blue	0.45 - 0.51	30
Band 3 - Green	0.53 - 0.59	30
Band 4 - Red	0.64 - 0.67	30
Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
Band 6 - SWIR 1	1.57 - 1.65	30
Band 7 - SWIR 2	2.11 - 2.29	30
Band 8 - Panchromatic	0.50 - 0.68	15
Band 9 - Cirrus	1.36 - 1.38	30
Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100 * (30)

Band	Wavelength	Useful for mapping
Band 1 - coastal aerosol	0.43 - 0.45	coastal and aerosol studies
Band 2 - blue	0.45 - 0.51	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
Band 3 - green	0.53 - 0.59	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 4 - red	0.64 - 0.67	Discriminates vegetation slopes
Band 5 - Near Infrared (NIR)	0.85-0.88	Emphasizes biomass content and shorelines
Band 6 - Short-wave Infrared (SWIR) 1	1.57 - 1.65	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 7 - Short-wave Infrared (SWIR) 2	2.11 - 2.29	Improved moisture content of soil and vegetation and thin cloud penetration
Band 8 - Panchromatic	0.50 - 0.68	15 meter resolution, sharper image definition
Band 9 - Cirrus	1.36 - 1.38	Improved detection of cirrus cloud contamination
Band 10 - TIRS 1	10.60 - 11.19	100 meter resolution, thermal mapping and estimated soil moisture
Band 11 - TIRS 2	11.5 - 12.51	100 meter resolution, Improved thermal mapping and estimated soil moisture

Come ottenere le scene Landsat?

http://landsat.usgs.gov/Landsat_Search_and_Download.php

Landsat Level 1 Data Products

Landsat Level 1 Data Products held in the USGS archives can be searched on the following pages:

EarthExplorer: <http://earthexplorer.usgs.gov> – allows geographical searches of data held in the USGS archives

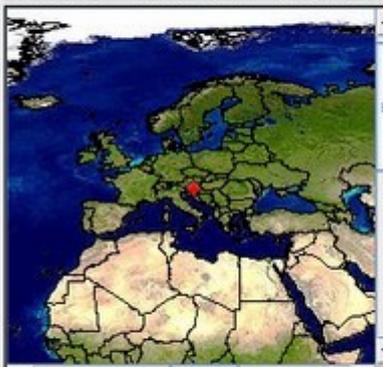
Global Visualization Viewer (GloVis): <http://glovis.usgs.gov> – a browse-based viewer for USGS Landsat Archive data sets

LandsatLook Viewer: <http://landsatlook.usgs.gov> - a prototype tool that allows rapid online viewing and access to the USGS Landsat archive

The screenshot displays the EarthExplorer web interface. On the left, a sidebar shows search criteria and a list of results. The main area features a satellite map of the Alpine region with a cyan search area. The search criteria summary is as follows:

Entity ID	Coordinates	Acquisition Date	Path	Row
LC81920282016176LGN00	46.0298, 12.07987	24-JUN-16	190	29
LC81910292016169LGN00	44.6082, 13.11595	17-JUN-16	192	28
LC81910292016169LGN00	46.0292, 13.63352	17-JUN-16	191	29
LC81900282016162LGN00	46.02948, 15.16884			

Downloadable



WRS-2 Path / Row: 191 28 Go
Lat / Long: 46.0 13.6 Go

Max Cloud: 100% [Left Arrow] [Up Arrow] [Down Arrow] [Right Arrow]

Scene Information:
ID: LE71910282011275ASN00
CC: 0% Date: 2011/10/2
Qty: 9 Product: ETM+ L1T

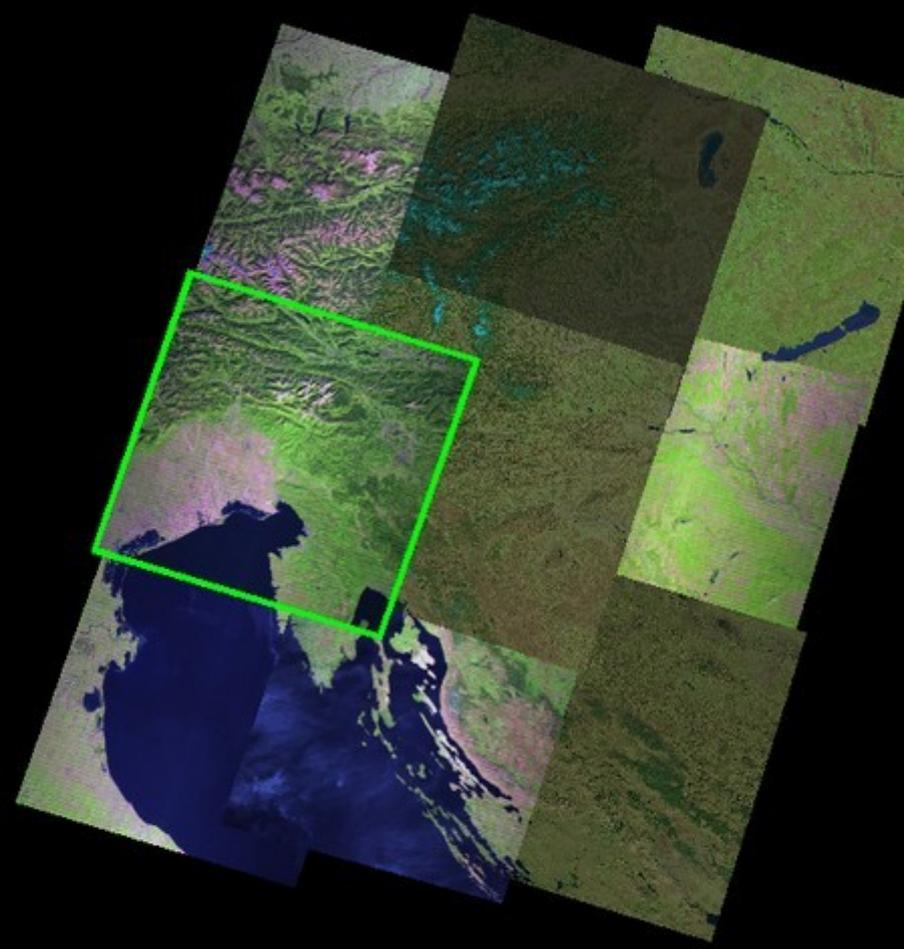
Oct 2011 Go

Prev Scene Next Scene

Landsat 4 - Present List

--	--	--

Add Delete Send to Cart



Welcome | About | Quick Guide | Contact Us | Help

Search the Landsat Archive

Years
from: 2003 to: 2016

Days of the Year
from: January 01 to: December 31

Maximum Cloud Cover
20%

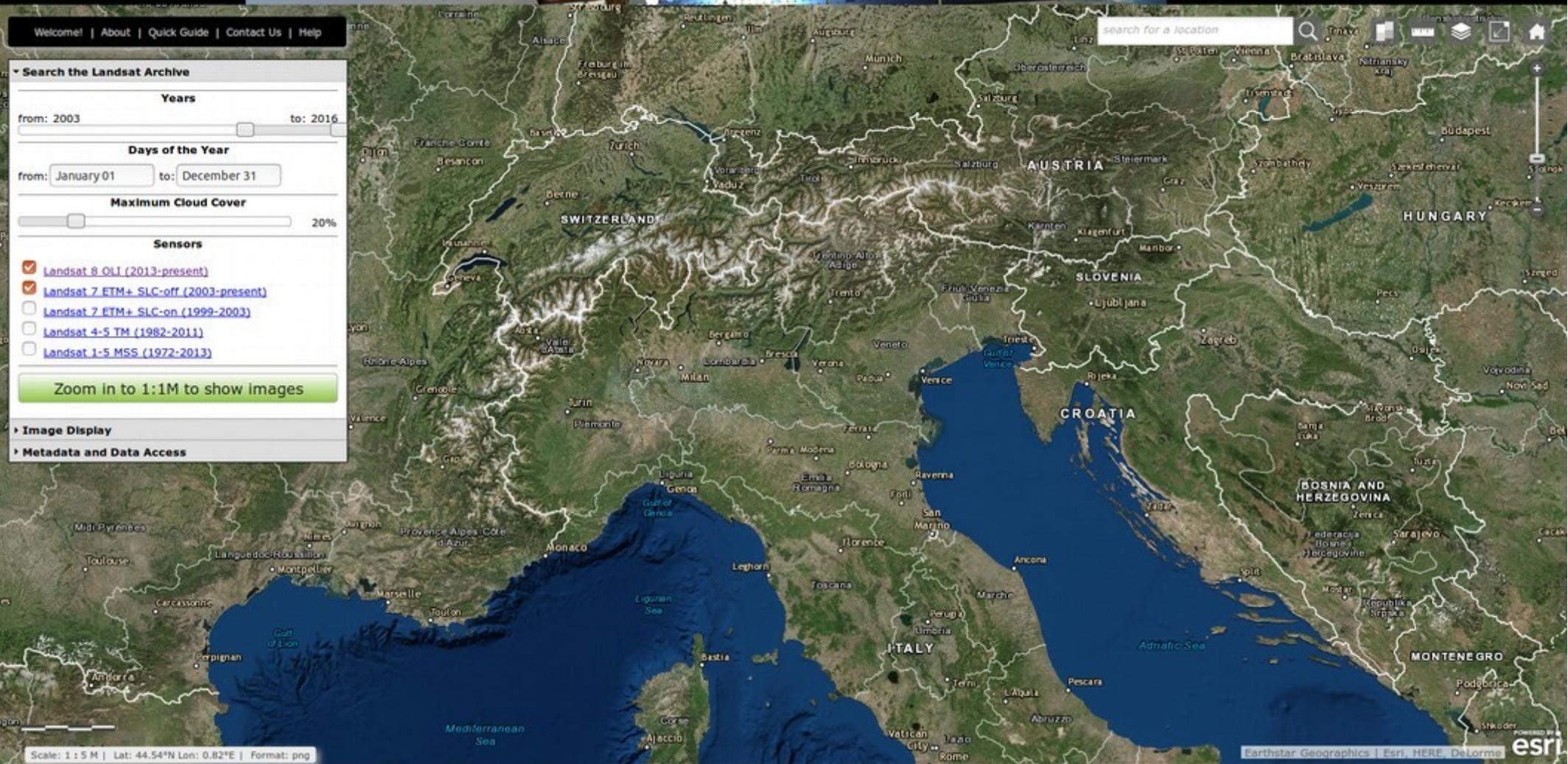
Sensors

- Landsat 8 OLI (2013-present)
- Landsat 7 ETM+ SLC-off (2003-present)
- Landsat 7 ETM+ SLC-on (1999-2003)
- Landsat 4-5 TM (1982-2011)
- Landsat 1-5 MSS (1972-2013)

Zoom In to 1:1M to show images

Image Display

Metadata and Data Access



Scale: 1 : 5 M | Lat: 44.54°N Lon: 0.82°E | Format: png

Earthstar Geographics | Esri, HERE, DeLorme
Powered by esri

ASTER



<http://asterweb.jpl.nasa.gov/index.asp>

L'acronimo sta per Advanced Spaceborne Thermal Emission and Reflection Radiometer. Il sensore è trasportato dal satellite Terra della NASA (lanciato nel Dicembre 1999). Si tratta di una cooperazione fra il Giappone (che ha costruito il sensore) e gli USA (che hanno fornito il satellite). Le immagini vengono elaborate e validate da un team di scienziati di entrambi i Paesi.

APRIL 1, 2016

All ASTER data products are now available at no charge to all users

In a joint announcement by the US and Japan, the entire ASTER archive was opened to the public. Any scene, and all derived products, can be ordered by anyone.

Click on the link to [Get ASTER Data](#) for information about data browse-and-ordering sites

Caratteristiche tecniche del sensore

Caratteristiche delle bande ASTER:

Sottosistema	N° banda	Range (µm)	Risoluzione Spaziale (m)	Applicazioni principali
VNIR (Visibile - Vicino infrarosso)	1	0.52 - 0.60	15	Cartografia di scogliere coralline Modelli numerici del terreno Geologia Monitoraggio dei ghiacciai Classificazione del territorio e detezione delle modificazioni Superfici ai poli e classificazioni delle nuvole Umidità del suolo Bilancio energetico Sviluppo urbano Stress e sviluppo della vegetazione Monitoring dei vulcani Cartografia delle zone umide
	2	0.63 - 0.69	15	
	3 Nadir locking 3 Backward locking	0.76 - 0.86	15 (Immagine stereoscopica Rapporto Base/Altezza = 0.6)	
SWIR (medio infrarosso)	4	1.60 - 1.70	30	Geologia Esplorazione mineraria Classificazione del territorio e detezione delle modificazioni Bilancio energetico Monitoring dei vulcani
	5	2.145 - 2.185	30	
	6	2.185 - 2.225	30	
	7	2.235 - 2.285	30	
	8	2.295 - 2.365	30	
	9	2.36 - 2.43	30	
TIR (Infrarosso termico)	10	8.125 - 8.475	90	Monitoraggio degli incendi Geologia Classificazione del territorio e detezione delle modificazioni Superfici ai poli e classificazioni delle nuvole Umidità del suolo Emissività della superficie Bilancio energetico Cinetica della temperatura superficiale Sviluppo urbano Stress della vegetazione Monitoring dei vulcani Cartografia delle zone umide
	11	8.475 - 8.825	90	
	12	8.925 - 9.275	90	
	13	10.25 - 10.95	90	
	14	10.95 - 11.65	90	

Come ottenere le scene ASTER?

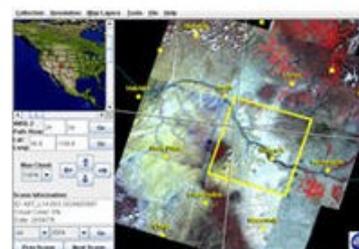
Get *ASTER* Data

NASA Reverb



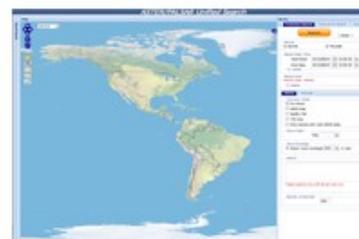
Search the entire ASTER data archive. ALL products are available to all users at no cost: ASTER L1A, L1B, L1T; Higher Level Data Products (HLDPs) created from L1A; the ASTER Global Digital Elevation Model (GDEM), and the North American ASTER Land Surface Emissivity Database (NAALSED). Registration is required for all users.

GloVis



Search the entire ASTER data archive using a browse-based map interface. The following products are available to all users at no cost: ASTER L1B and L1T data (day and night), and Higher Level Data Products (HLDPs). All users can create and order Terralook collections of ASTER L1B JPEGs, and selected Landsat scenes.

ASTER/AIST



Search the entire ASTER data archive. Order: 1) pseudocolor natural color image as WMS/KML or 2) Level 3 orthorectified bands 1-14 with 30m DEM.

Earth Explorer



No charge ASTER data for all users: ASTER L1B and L1T data, the ASTER GDEM, and NAALSED products for the world. Select "NASA LPDAAC collections" under "Data Sets".

<http://asterweb.jpl.nasa.gov/data.asp>

ESA – Sentinel 2

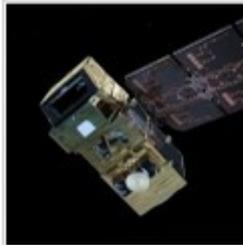


Sentinel Online



Sentinel-2 è un programma/satellite europeo (il primo satellite della coppia prevista è stato lanciato nel Giugno 2015 da ESA)

- SENTINEL-2



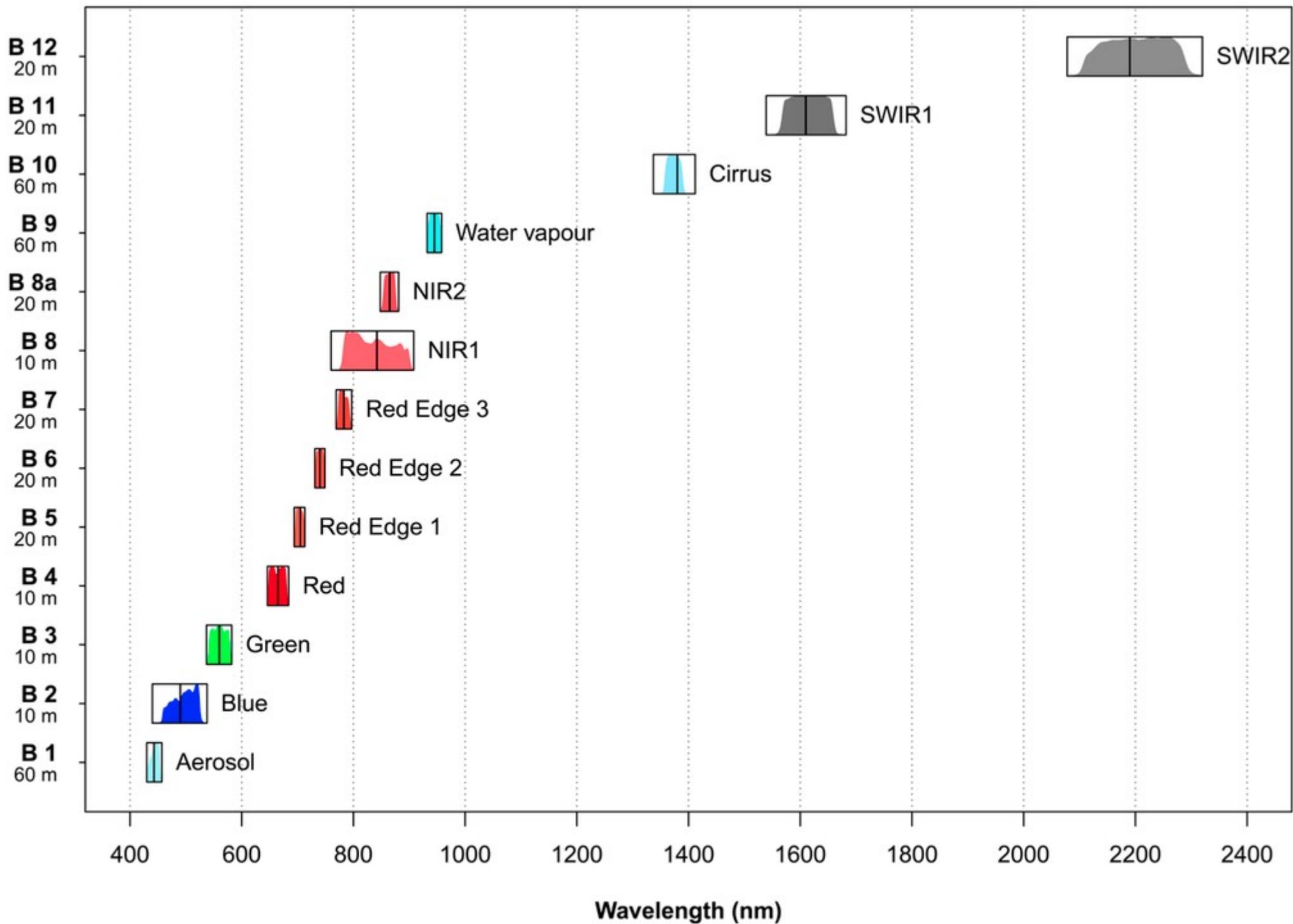
The full SENTINEL-2 mission comprises twin polar-orbiting satellites in the same orbit, phased at 180° to each other.

The mission will monitor variability in land surface conditions, and its wide swath width and high revisit time (10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which results in 2-3 days at mid-latitudes) will support monitoring of changes to vegetation within the growing season. The coverage limits are from between latitudes 56° south and 84° north.

Caratteristiche tecniche del sensore

Table 1: Wavelengths and bandwidths of MSI instrument spatial resolutions.

Spatial Resolution (m)	Band Number	Central Wavelength (nm)	Bandwidth (nm)
10	2	490	65
	3	560	35
	4	665	30
	8	842	115
20	5	705	15
	6	740	15
	7	783	20
	8a	865	20
	11	1 610	90
	12	2 190	180
60	1	443	20
	9	945	20
	10	1 380	30



- Spatial Resolution

The spatial resolution of SENTINEL-2 is dependent on the particular spectral band:

10 metre spatial resolution:

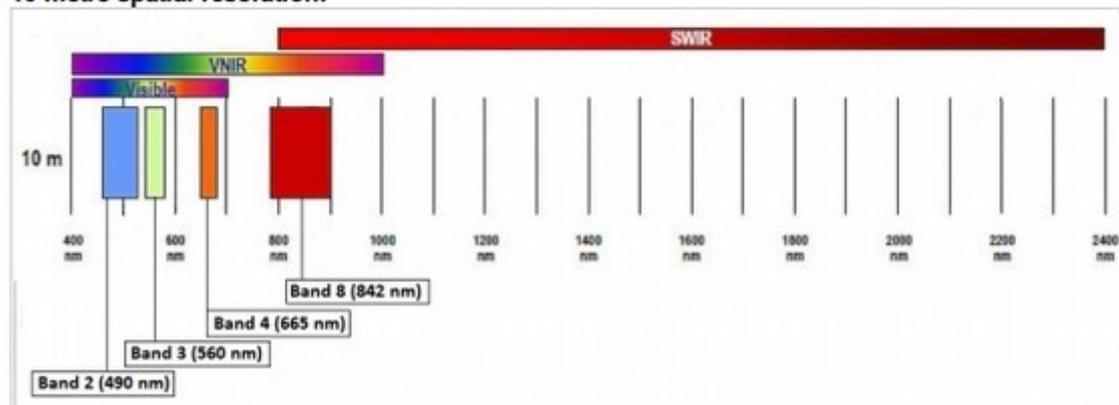


Figure 1: SENTINEL-2 10 m spatial resolution bands: B2 (490 nm), B3 (560 nm), B4 (665 nm) and B8 (842 nm)

20 metre spatial resolution:

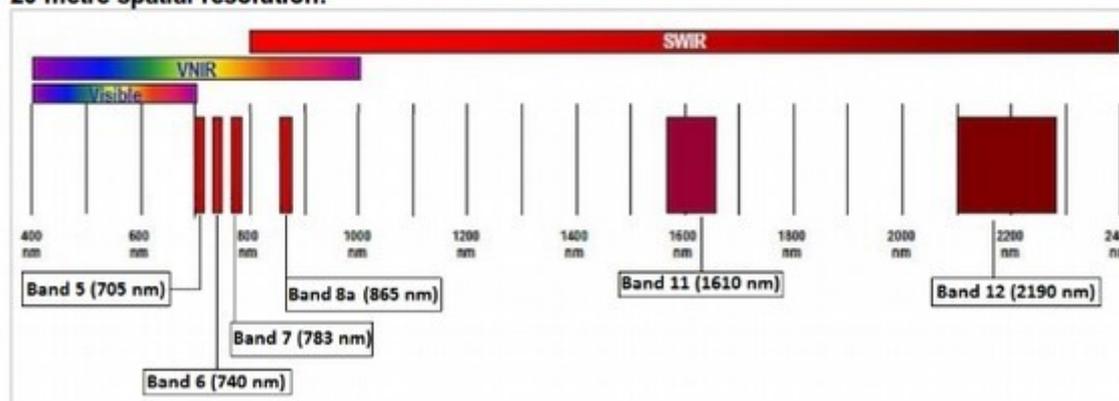


Figure 2: SENTINEL-2 20 m spatial resolution bands: B5 (705 nm), B6 (740 nm), B7 (783 nm), B8a (865 nm), B11 (1610 nm) and B12 (2190 nm)

60 metre spatial resolution:

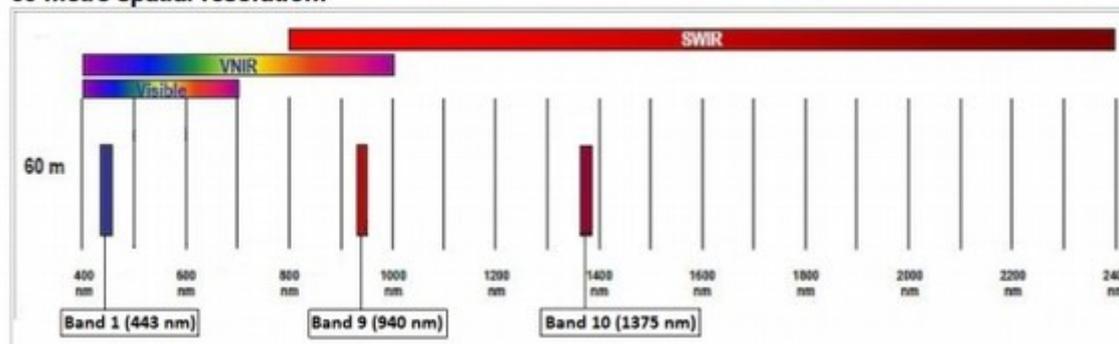
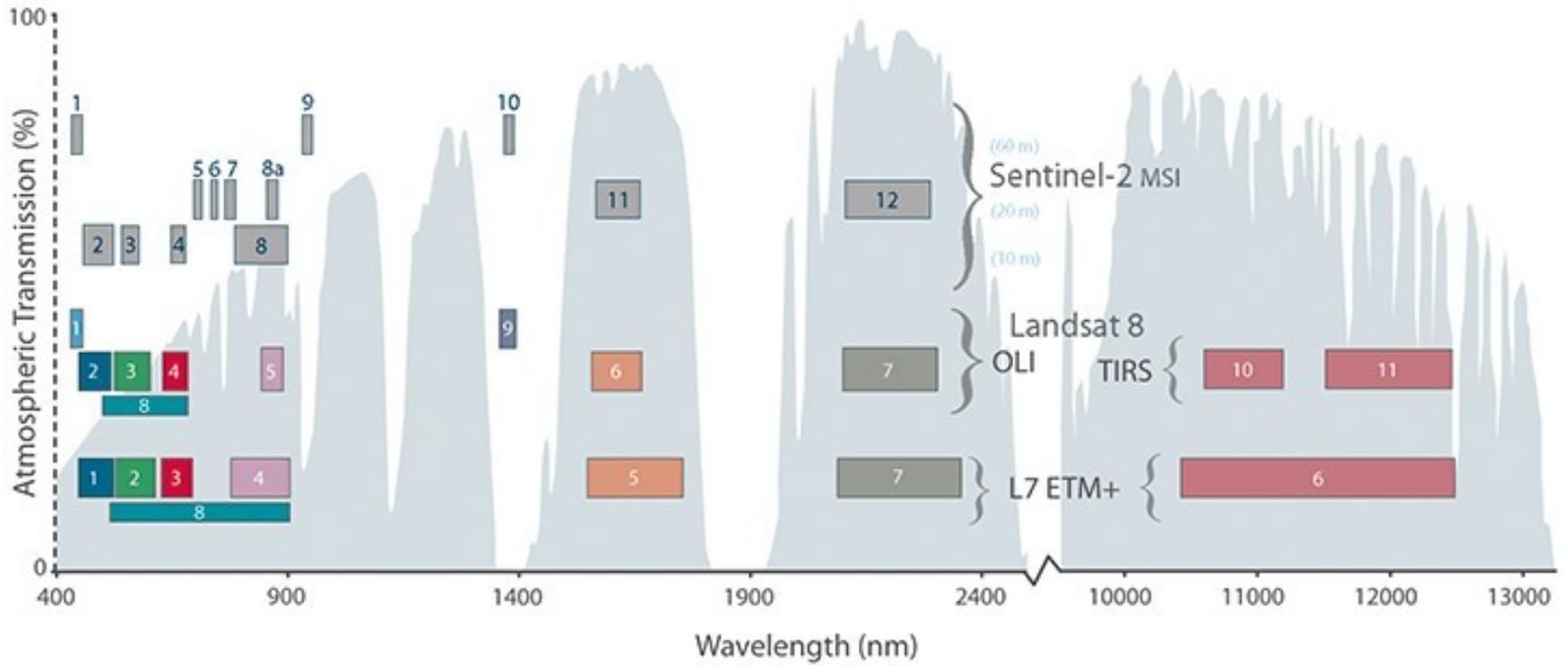


Figure 3: SENTINEL-2 60 m spatial resolution bands: B1 (443 nm), B9 (940 nm) and B10 (1375 nm)

Comparison of Landsat 7 and 8 bands with Sentinel-2



Ampiezza delle immagini

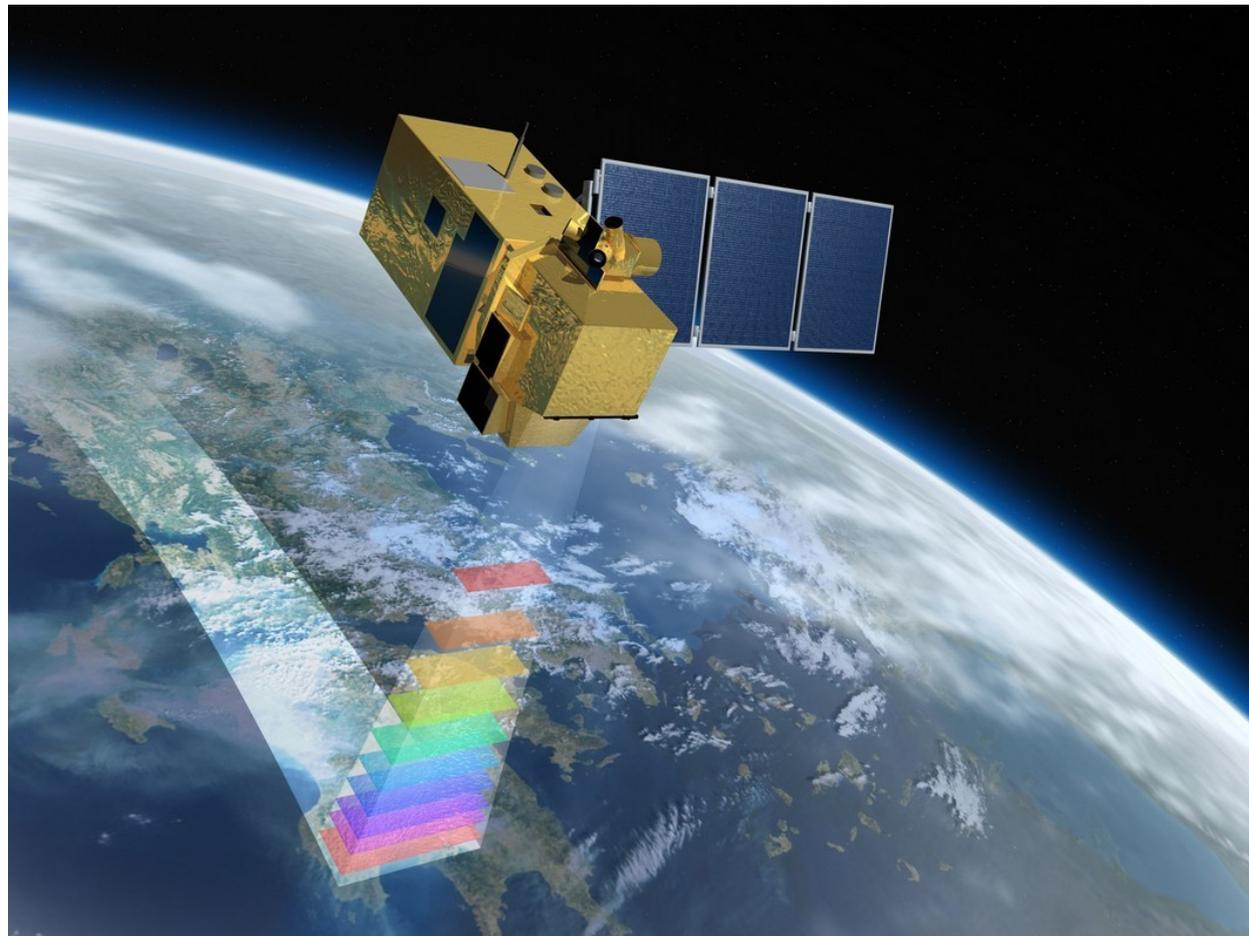
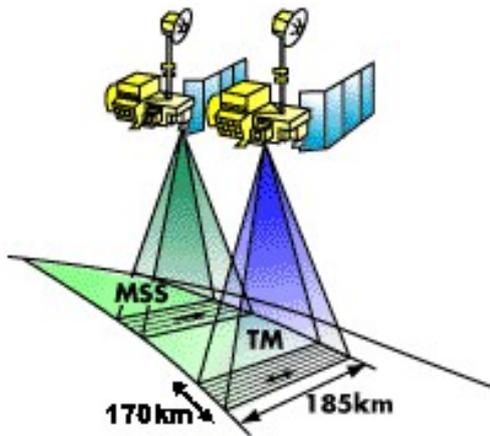
Dipende dall'estensione in larghezza sul terreno ripresa dal sensore (Swath Width – SW):

Per Landsat è 185 km

Per ASTER è 60 km

Per Sentinel-2 è 290 km

Lo SW, pur essendo una sola delle due dimensioni, è legato alle dimensioni totali dell'immagine in quanto quest'ultima viene generalmente “tagliata” in modo da formare un quadrato (quindi, ad esempio, nel caso di Landsat l'immagine a disposizione corrisponde ad un quadrato di territorio di circa 185 km di lato).



Come ottenere le scene di Sentinel 2?

<https://scihub.copernicus.eu/dhus/#/home>

The image shows a screenshot of the Sentinel Scientific Data Hub (SDH) interface. The top left features the logos for the European Union, ESA, and Copernicus. The main header reads "Sentinels Scientific Data Hub". Below the header is a search bar with the text "Insert search criteria...".

The left sidebar displays a list of products, showing "Display 1 to 25 of 159 products." and a "Select All" button. The list contains several Sentinel-2 MSI products, each with a thumbnail, a product ID, and a download URL. The products listed are:

- S2A MSI S2A_OPER_PRD_MSIL1C_PDMC_20160628T191749_R022_V20160628T101826_2016062...**
Download URL: <https://scihub.copernicus.eu/dhus/odata/v1/Products/'c06f31b5-fb7b-4108-90e1>
Mission: Sentinel-2; Instrument: MSI; Sensing Date: 2016-06-28T10:18:26.000Z; Size: 2.70 GB
- S2A MSI S2A_OPER_PRD_MSIL1C_PDMC_20160628T172504_R022_V20160628T101026_2016062...**
Download URL: <https://scihub.copernicus.eu/dhus/odata/v1/Products/'06f5d27f-00b8-4bab-80f1>
Mission: Sentinel-2; Instrument: MSI; Sensing Date: 2016-06-28T10:10:26.000Z; Size: 7.01 GB
- S2A MSI S2A_OPER_PRD_MSIL1C_PDMC_20160628T172626_R022_V20160628T101026_2016062...**
Download URL: <https://scihub.copernicus.eu/dhus/odata/v1/Products/'6f122312-30b8-4a44-888>
Mission: Sentinel-2; Instrument: MSI; Sensing Date: 2016-06-28T10:10:26.000Z; Size: 3.91 GB
- S2A MSI S2A_OPER_PRD_MSIL1C_PDMC_20160625T190927_R122_V20160625T100617_2016062...**
Download URL: <https://scihub.copernicus.eu/dhus/odata/v1/Products/'7419156f-c69c-4d25-a4d1>
Mission: Sentinel-2; Instrument: MSI; Sensing Date: 2016-06-25T10:06:17.000Z; Size: 6.13 GB
- S2A MSI S2A_OPER_PRD_MSIL1C_PDMC_20160625T190742_R122_V20160625T100617_2016062...**
Download URL: <https://scihub.copernicus.eu/dhus/odata/v1/Products/'e565044f-991a-4cda-9b31>
Mission: Sentinel-2; Instrument: MSI; Sensing Date: 2016-06-25T10:06:17.000Z; Size: 5.18 GB
- S2A MSI S2A_OPER_PRD_MSIL1C_PDMC_20160622T171027_R079_V20160622T095030_2016062...**
Download URL: <https://scihub.copernicus.eu/dhus/odata/v1/Products/'2719c569-fcc7-4376-acd7>
Mission: Sentinel-2; Instrument: MSI; Sensing Date: 2016-06-22T09:50:30.000Z; Size: 5.67 GB
- S2A MSI S2A_OPER_PRD_MSIL1C_PDMC_20160621T190408_R065_V20160621T102024_2016062...**
Download URL: <https://scihub.copernicus.eu/dhus/odata/v1/Products/'06bd32c5-edd7-4430-a36>
Mission: Sentinel-2; Instrument: MSI; Sensing Date: 2016-06-21T10:20:24.000Z; Size: 5.51 GB

The right side of the interface shows a map of Europe. A green rectangular area highlights a search region covering parts of Germany, Poland, Czech Republic, Austria, and Hungary. A yellow rectangular area is overlaid on the green area, indicating a specific search footprint. The map includes labels for various countries and cities, such as Deutschland, Polen, Česko, Österreich, Magyarország, and others.