

GEOG 357

LECTURE 16

1

House Keeping

Lectures

- Thurs 18th - Microwave - RADAR
- Tues 23rd - LiDAR
- Thurs 25th - Course Review

Final Submissions

- Nov 16th (today) - Article Review
- Nov 30th -Final Exam
- Dec 2nd - Project Demos
- Dec 6th - Project Submission

2

New millennium sensors: Earth Observation (EO)

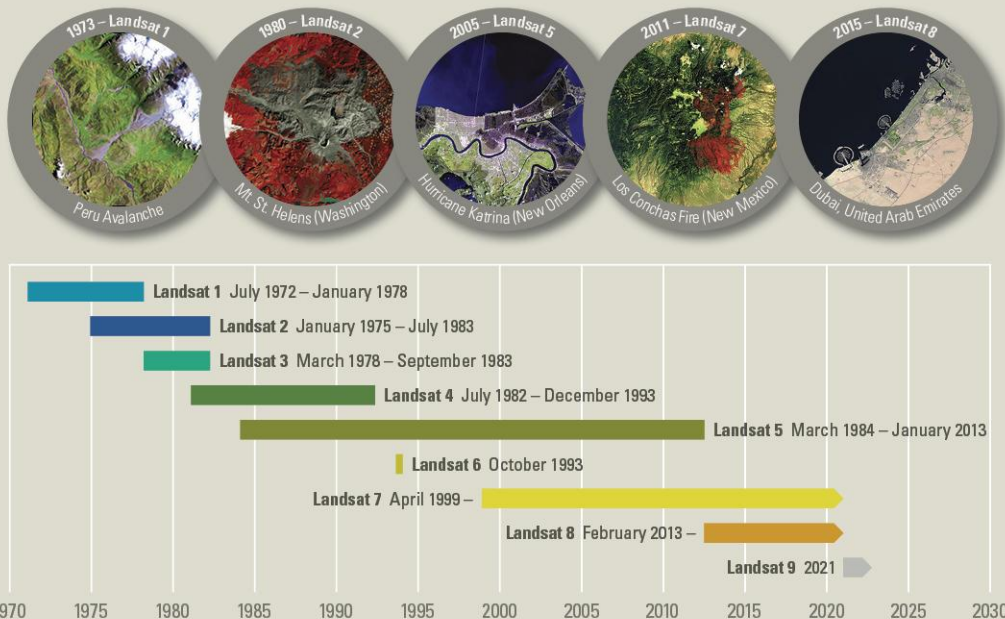
- Landsat (NASA) 1970s-> 1999-> 2013->
- ASTER and MODIS (NASA) 2000 ->
- Sentinel (ESA) 2015 ->
- High resolution satellites 2000->

- RADAR
- LiDAR



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Landsat Missions: Imaging the Earth Since 1972



4

Landsat 8 (OLI) 2013->



Highest settlement in the world, Peru. 5100 m ASL

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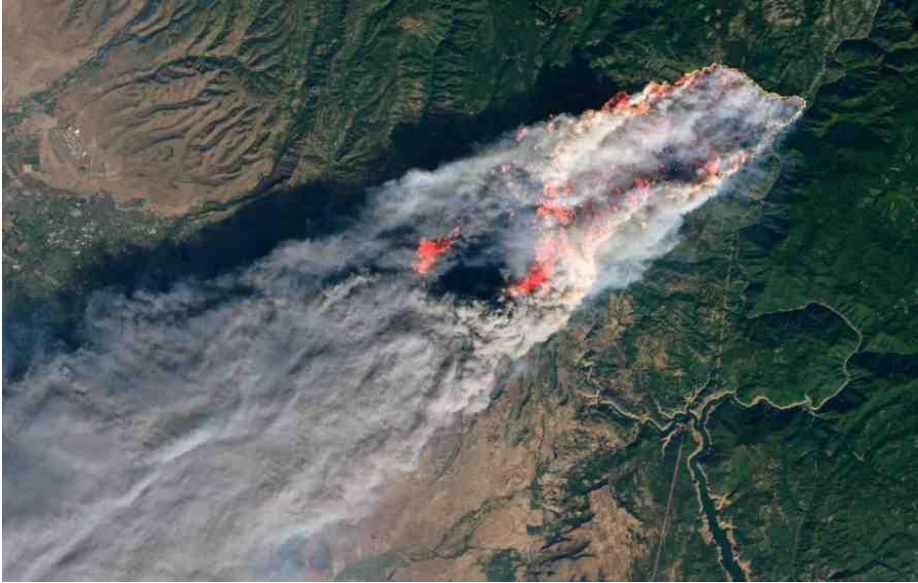
Landsat 9 OLI 2

- First light. The collected data are for still evaluation.
- Improved Radiometric Resolution
 - 14 bit vs 12 for Landsat 8
- <https://earthobservatory.nasa.gov/images/149058/first-light-from-landsat-9?src=eoaiotd>

Presentation Title



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Landsat 8 OLI 432 composite plus mid-IR (band 6) for fires
 Landsat 7 continuing but without Scan Line Calibration
 Swath ~180km, L7 central stripe free ~ 20km

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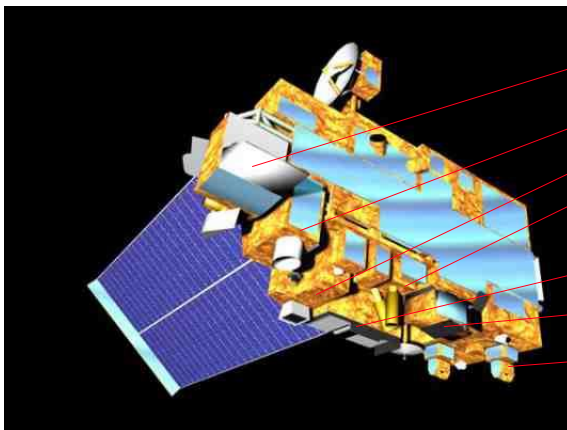
Terra Satellite

data since Feb 24, 2000 (launched 18 Dec 1999)



Terra is the flagship of NASA's Earth Science Enterprise.

ASTER is the 'zoom lens' of Terra..



MODIS

ASTER (TIR)

ASTER (SWIR) x2008

ASTER (VNIR)

MISR

MOPITT

CERES

8

TERRA: THE EARTH OBSERVING SYSTEM (EOS) AM-1

<https://terra.nasa.gov/about/terra-instruments>

Terra Instruments

ASTER Advanced Spaceborne Thermal Emission and Reflection Radiometer

- JAPAN, NASA cooperative effort

MODIS Moderate-resolution Imaging Spectroradiometer

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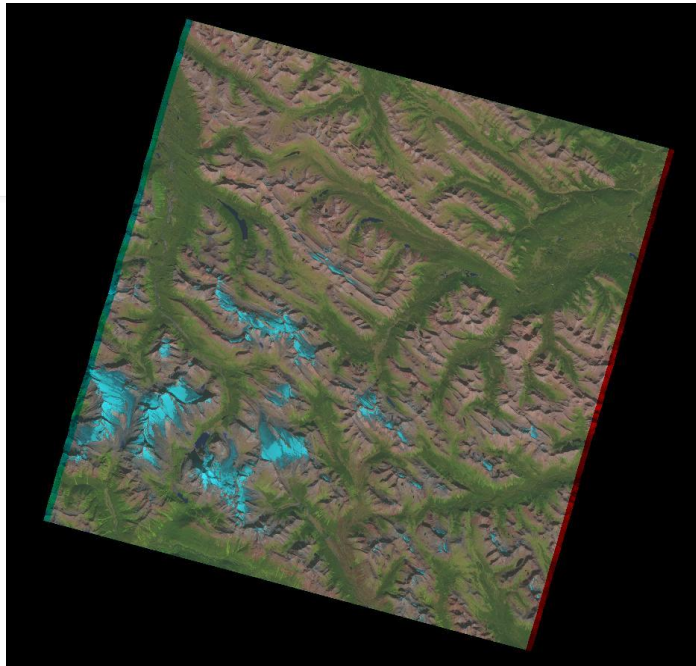
CERES Clouds and the Earth's Radiant Energy System (thermal)

MISR Multi-angle Imaging Spectro-Radiometer

VNIR at 26, 46 60, 70 degrees

MOPITT Measurement of Pollution in the Troposphere (CO, CH₄)
<https://mopitt.physics.utoronto.ca/> (CANADA, US, UK team of scientists)

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ASTER
Landsat-like
Sept 2007
Mt. Robson
15/30m
SWIR
failed
April 2008

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ASTER bands – band 3 has two modes: 3N and 3B

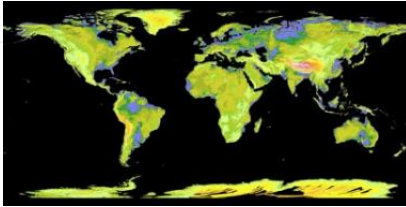
<u>Band</u>	<u>Wavelength (microns)</u>	<u>Spatial Resolution (m)</u>
Visible to Near-Infrared Bands		
1	0.52 ♦ 0.60	15
2	0.63 ♦ 0.69	15
3	0.76 ♦ 0.86	15
Shortwave Infrared Bands		
4	1.60 ♦ 1.70	30
5	2.145 ♦ 2.185	30
6	2.185 ♦ 2.225	30
7	2.235 ♦ 2.285	30
8	2.295 ♦ 2.365	30
9	2.360 ♦ 2.430	30
Mid-infrared (Thermal) Bands		
10	8.125 ♦ 8.475	90
11	8.475 ♦ 8.825	90
12	8.925 ♦ 9.275	90
13	10.25 ♦ 10.95	90
14	10.95 ♦ 11.65	90

Failed 2008

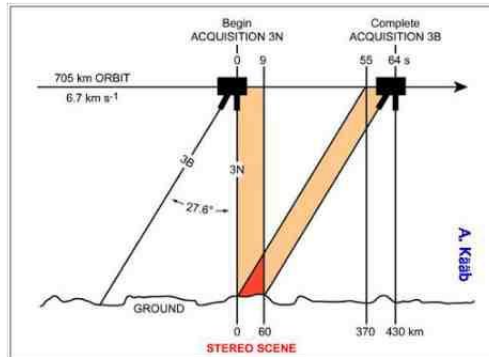
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ASTER - imagery and DEMs 2000-

Global DEM to 83 degrees latitude



Sample ASTER draped image



ASTER stereo geometry and timing of the nadir-band 3N and the back-looking sensor 3B. An ASTER nadir scene of approximately 60 km length, and a corresponding back looking scene (27.6° off-nadir) acquired about 60 seconds later, form a stereo pair.

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<https://asterweb.jpl.nasa.gov/gallery.asp>



SEARCH ASTER

- HOME
- MISSION
- GALLERY
- Archaeology
- Cities
- Geology
- Glaciers
- Hydrology
- Land Use
- Natural Hazards
- Volcanoes

ASTER's Satellite Image Gallery

20 Most Recent Additions to the Gallery

Image of the Week
Sea of Galilee, Israel

Gravity Wave Detectors

Aldan, Siberia, Russia

Tao-Rusyr Volcano, Kuril Islands

Lake Fitri, Chad

Nishinoshima Volcano, Japan

Mount Whaleback Iron Ore Mine, Australia

2020 AI Jowf

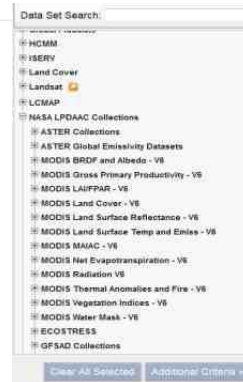
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MODIS (Moderate-resolution Imaging Spectroradiometer)

EarthExplorer datasets

MODIS SPECIAL THEMES

MODIS Team Member	MODIS Product
E. Vermote	Surface Reflectance
Z. Wan	Land Surface Temperature
A. Strahler/J. P. Muller	BRDF/Albedo
A. R. Huete/C. O. Justice	Vegetation Indexes
R. B. Myneni/S. W. Running	LAI/FPAR
C. O. Justice/Y. J. Kaufman	Fires/Burned Area
D. Hall	Snow/Ice/Sea Ice
J. R. G. Townshend/A. Strahler	Land Cover/Land Cover Change
S. W. Running	PSN/NPP



Launched by NASA in 1999 on the [Terra](#) (EOS AM) satellite, and in 2002 on the [Aqua](#) (EOS PM) satellite.

Terra: 10.30am descending

Aqua: 1.30pm ascending

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MODIS: MODerate-resolution Imaging Spectroradiometer

36 spectral bands ranging in wavelength from 0.4 μm to 14.4 μm and at spatial resolutions between 250m and 1km. Swath: 2330 km Earth covered 1-2 days
Designed to combine some of the characteristics of AVHRR and Landsat TM

'Superspectral' (vs Multispectral)

MODIS is THE main medium resolution EO satellite sensor

Reflected Solar Bands			Emissive Bands
Aggregated 250 m	Aggregated 500 m	1 km	1 km
Band 1 (620-670 nm)	Band 3 (459-479 nm)	Band 8 (405-420 nm)	Band 20 (3.660-3.840 μm)
Band 2 (841-876 nm)	Band 4 (545-565 nm)	Band 9 (438-448 nm)	Band 21 (3.929-3.989 μm)
	Band 5 (1230-1250 nm)	Band 10 (483-493 nm)	Band 22 (3.939-3.989 μm)
	Band 6 (1628-1652 nm)	Band 11 (526-536 nm)	Band 23 (4.020-4.080 μm)
	Band 7 (2105-2155 nm)	Band 12 (546-556 nm)	Band 24 (4.433-4.498 μm)
		Band 13L (662-672 nm)	Band 25 (4.482-4.549 μm)
		Band 13H (662-672 nm)	Band 27 (6.535-6.895 μm)
		Band 14L (673-683 nm)	Band 28 (7.175-7.475 μm)
		Band 14H (673-683 nm)	Band 29 (8.400-8.700 μm)
		Band 15 (743-753 nm)	Band 30 (9.580-9.880 μm)
		Band 16 (862-877 nm)	Band 31 (10.780-11.280 μm)
		Band 17 (890-920 nm)	Band 32 (11.770-12.270 μm)
		Band 18 (931-941 nm)	Band 33 (13.185-13.485 μm)
		Band 19 (915-965 nm)	Band 34 (13.485-13.785 μm)
		Band 26 (1.360-1.390 μm)	Band 35 (13.785-14.085 μm)
			Band 36 (14.085-14.385 μm)

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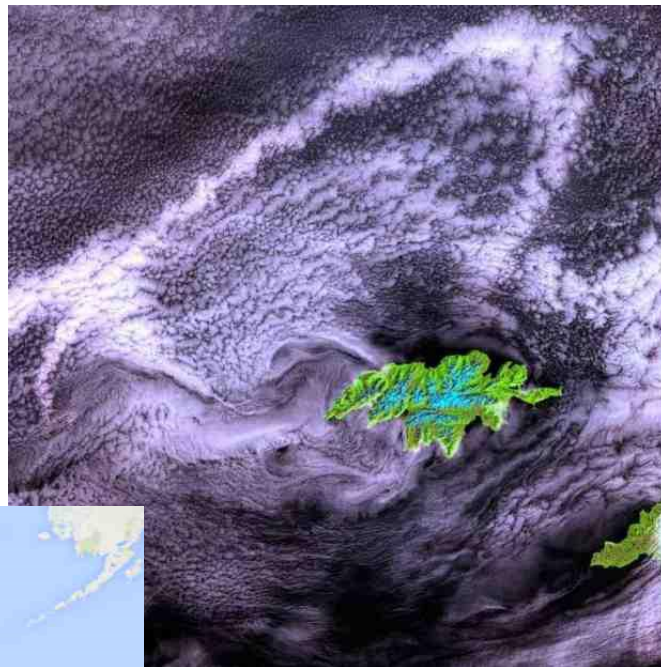
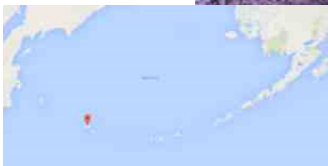


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Attu
Aleutian Islands
(MODIS image)

Westernmost
(and easternmost?)
point of North
America

50 km



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Sentinel Program 2015->

European
Space Agency
(ESA)
Heimay,
Iceland
Nov 1, 2018



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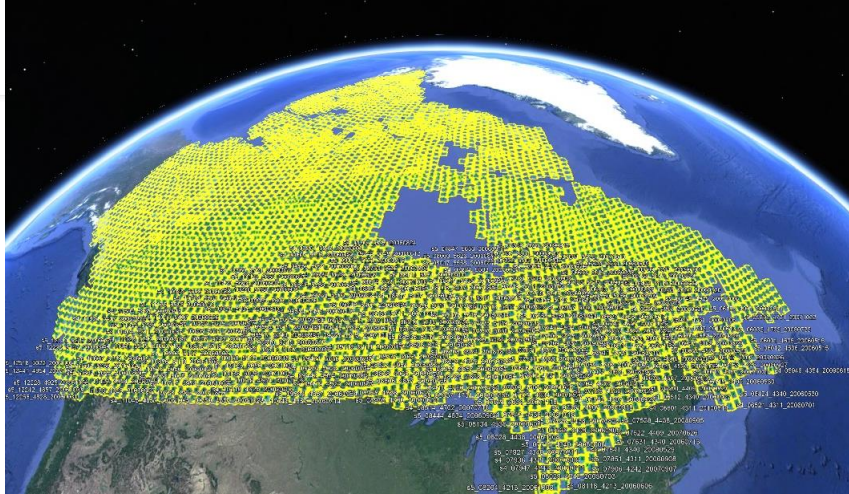
ESA Copernicus program: Sentinel - all free data

1a / b: April 2014 / 2016 RADAR 10m res.

Sentinel-2 Bands	Central Wavelength (μm)	Resolution (m)	Bandwidth (nm)
Band 1 – Coastal aerosol	0.443	60	20
Band 2 – Blue	0.490	10	65
Band 3 – Green	0.560	10	35
Band 4 – Red	0.665	10	30
Band 5 – Vegetation Red Edge	0.705	20	15
Band 6 – Vegetation Red Edge	0.740	20	15
Band 7 – Vegetation Red Edge	0.783	20	20
Band 8 – NIR	0.842	10	115
Band 8A – Narrow NIR	0.865	20	20
Band 9 – Water vapour	0.945	60	20
Band 10 – SWIR – Cirrus	1.375	60	20
Band 11 – SWIR	1.610	20	90
Band 12 – SWIR	2.190	20	180

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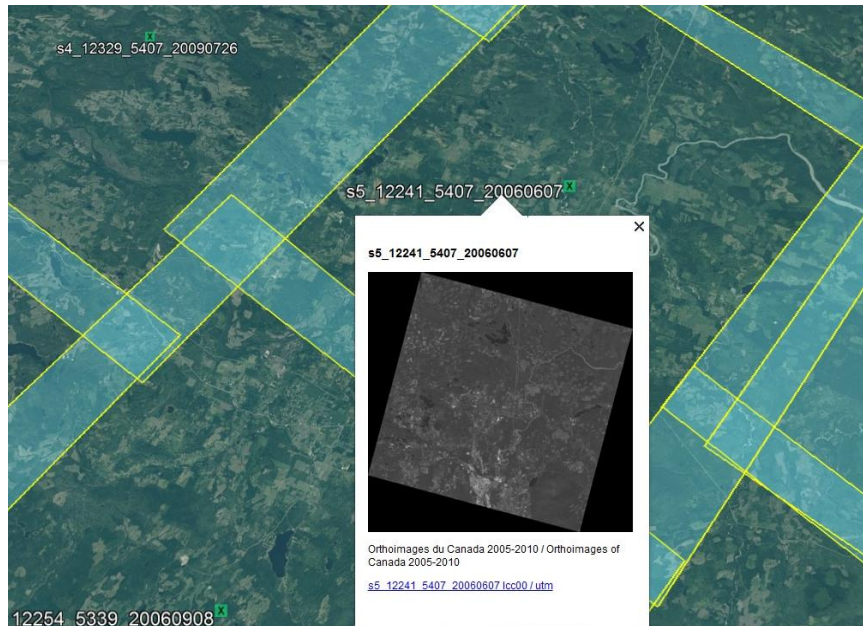
GEOBASE SPOT 4/5: Canada/France agreed to cover Canada 2005-2010 at 10/20m resolution; cloud free is not always guaranteed



https://ftp.maps.canada.ca/pub/nrcan_rncan/image/spot/geobase_orthoimage_s

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Zoom into your area, click on x and see the file name—coded by Lat/long



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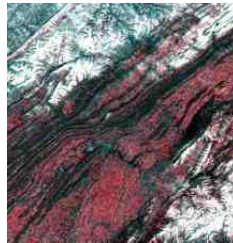
Highest resolution imagery in the old millennium

1959-72 Corona spy photos: 1.8 – 7.5 m resolution

1986: SPOT 1 PAN 10m Multi 20m



Indian Remote Sensing IRS-1C 1995:
Panchromatic (PAN) camera of 6 m res. (right)
Linear Imaging Self Scanner (LISS-3) 23.6m (left)
Wide Field Sensor (WiFS) 189m centre



Toronto



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High resolution **corporate** satellites 2000->

Ikonos: launched late 1999; first data sold Jan 1, 2000

Resolution: Pan 1m Multispectral 4m



Venice

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Ikonos 1m pixels: Whistler Olympic park (Jan 16, 2010)

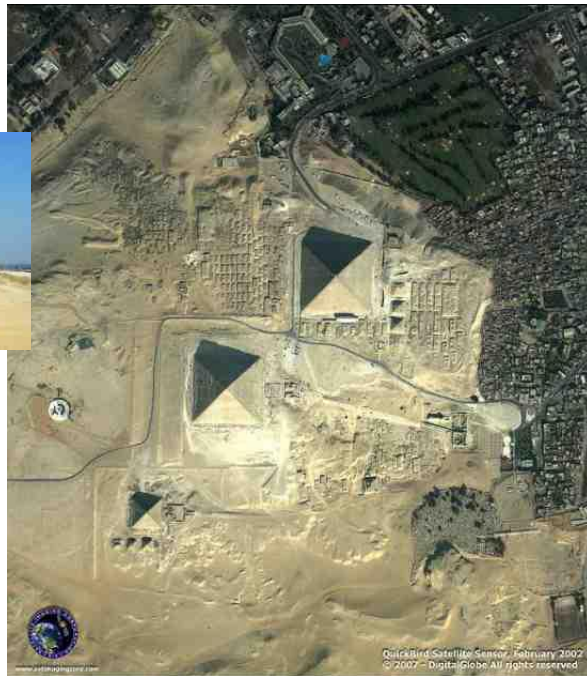


(For 2010 Winter Olympics)

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Quickbird 2001

Pan 60cm MS 2.4m



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GeoEye (launched by Google) 2008
 41 / 46cm PAN 1.65m MS
 Obama Inauguration (Jan 2009)



→ GeoEye 2 - PAN 31cm 2016 (Trump Inauguration ? 😊)

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Worldview3 2014

Rainbow Range
 Chilcotin, BC 31cm
 PAN: 31cm
 VNIR: 1.24m
 SWIR: 3.72m
 (8 bands)

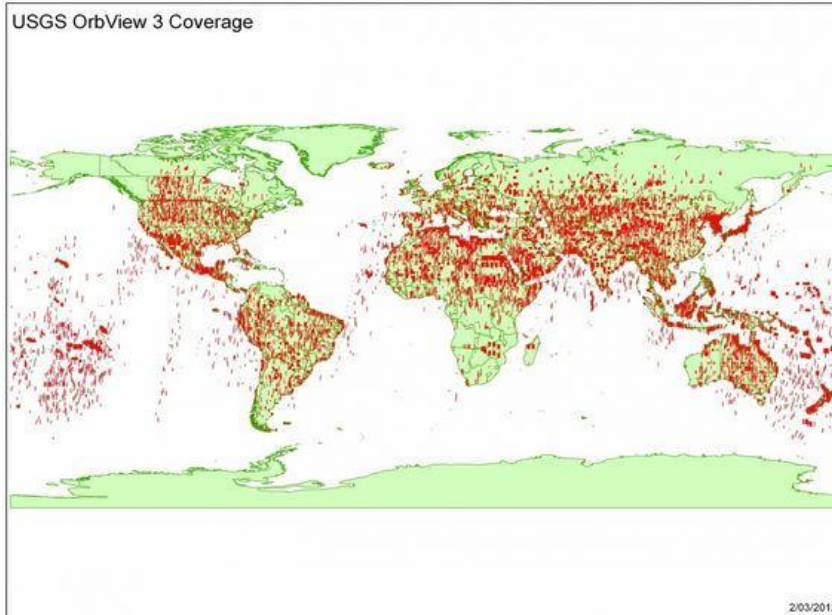


EarthExplorer datasets



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Ikonos – for government departments only Orbview (high res.) image data on EarthExplorer



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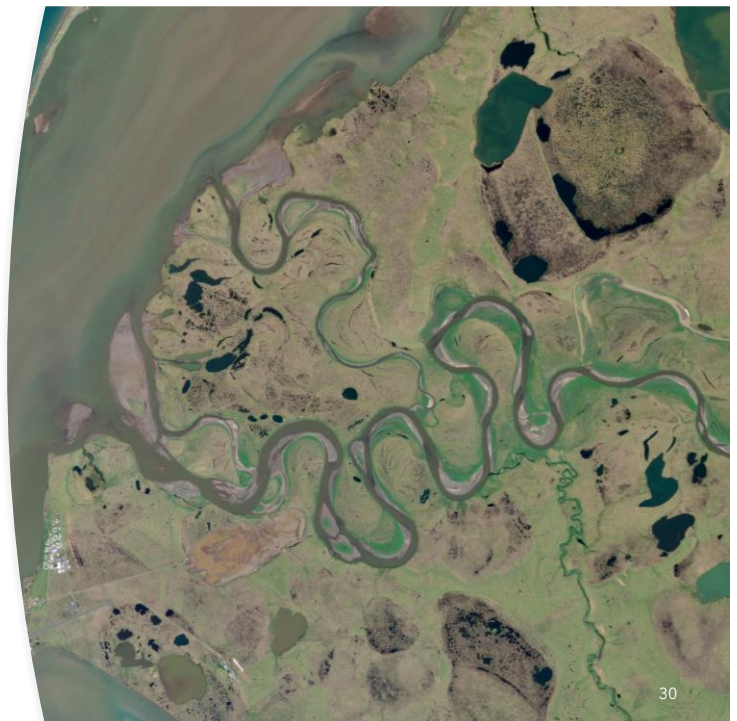
Planet Labs

Since 2010

3-5 m resolution

- <https://www.planet.com/gallery/#!/post/expansion-of-asia-pacific-airline-storage>

Presentation Title



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Fusion / Merge /Pansharpening

Satellite sensor PAN MS (metres)

Landsat 7 ETM+ 15 / 30

Landsat 8 OLI 15 / 30

SPOT 1-4 10 / 20

SPOT 5 5 / 10

SPOT 6-7 1.5 / 6

High-resolution

Ikonos 1 / 4

Quickbird 0.6 / 2.4

Worldview 0.31 / 1.24

Planet Labs 0.5 / 3-5

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Selected New millennium High resolution sensors

Launched by corporations, not always countries

Date	Sensor	Bands*	Pixel (m)	Swath (km)	Orbit (km)	Data
1999	Ikonos	RGBN	1 / 4	11.3	681	11 bit
2001	Quickbird	RGBN	0.6/2.4	16.5	450	11
2003	Orbview 3	RGBN	1 / 4	8	470	11
2007	Worldview 1	RGBN	0.5 / 2	17.6	496	11
2008	GeoEye 1	RGBN	.41 / 1.65	15	681	11
2009	Worldview 2	8 bands	.46 / 1.85	16.4	770	11
2014	Worldview 3	Vis-MIR	.31 / 1.24	13.1	617	11
2016	Worldview 4 = GeoEye2	= same as Worldview 3			617	11

* and higher resolution Panchromatic band

<https://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/>

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More New millennium High resolution sensors

Date	Sensor	Bands	Pixel (m)	Swath (km)	Orbit (km)	Country
2009	Deimos 1	GRN	22	600	625 8-10 bit	Spain/UK
2011	Pleiades	RGBN	0.5/2.0		?	France
2012	Kompsat	RGBN	0.7/2.8		14 bit	S.Korea
2017	Formosat	RGBN	0.5/2.0		14 bit	Taiwan

Also: Gokturk, DubaiSat, KoreaSat, KazeoSat, CartoSat, Gaofen

<https://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/>