UNIVERSITY OF TWENTE.

SENSORS, ORBIT AND INSTRUMENT CHARACTERISTICS

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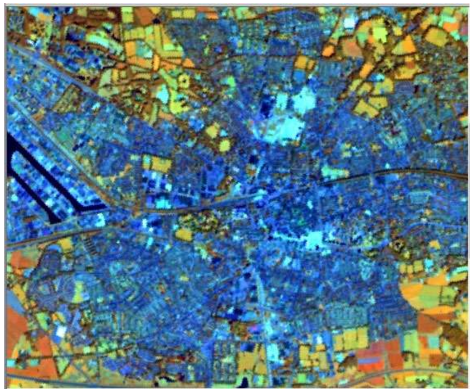
THIS PRESENTATION INCLUDES MOVIES

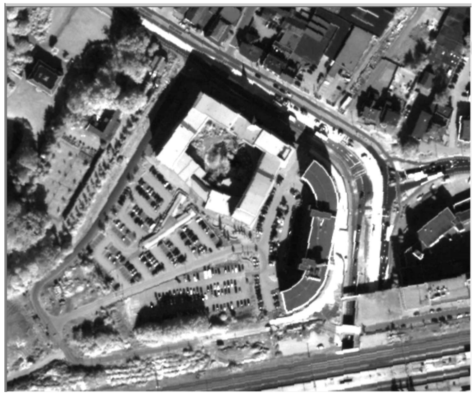
OBJECTIVES

- Understand the main elements related to orbits and viewing from space, types of sensors, scanning mechanisms
- Recognise the 4 different characteristics of the images that have been acquired from EO sensors and translate a spatial problem into 4 **image requirements** and **select** an appropriate sensor
- Activities:
  - Lecture, demo and Group discussion
  - Practical exercises:
    - Review several sensor characteristic calculations
    - Write a 1 page on “sensor resolutions”
  - Reference materials: ITC Textbook GIScience, Read Chapter 4.1, 4.1.1, 4.1.2. and 4.1.3. With an emphasis on satellites and satellite missions

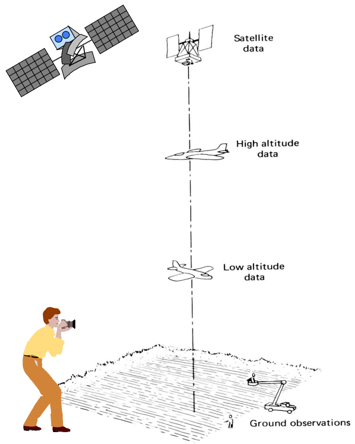
WHAT IS THE BEST IMAGE?

Enschede (left) and the old ITC building (right)



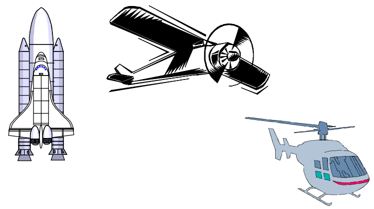


PLATFORMS CARRY SENSORS!!



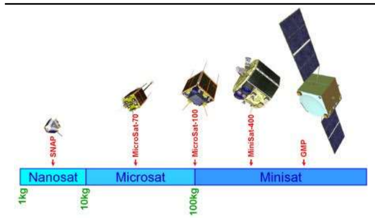
Sensing from 1 meter to 36,000 km height

Sensors are mounted on Platforms:
- Ground based
- Airborne
- **Spaceborne**



Here focus on space-borne sensors

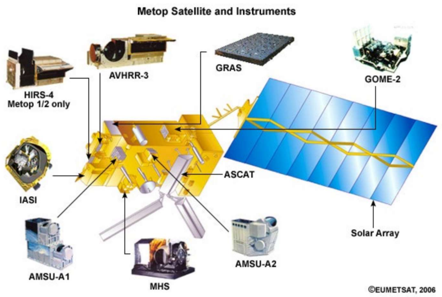
SPACE BORNE REMOTE SENSING: MISSIONS



Larger satellites carry multiple sensor and instruments

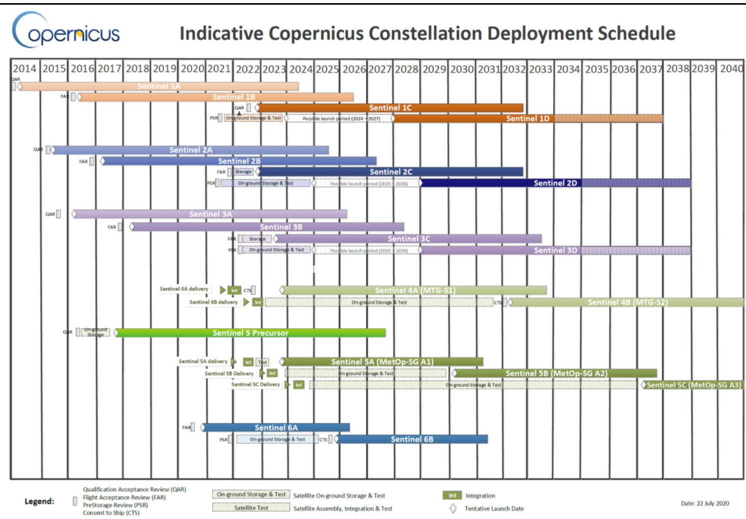
Mission characteristics:

- Platform
- Orbit
- Sensor(s)



MISSIONS OVERVIEW

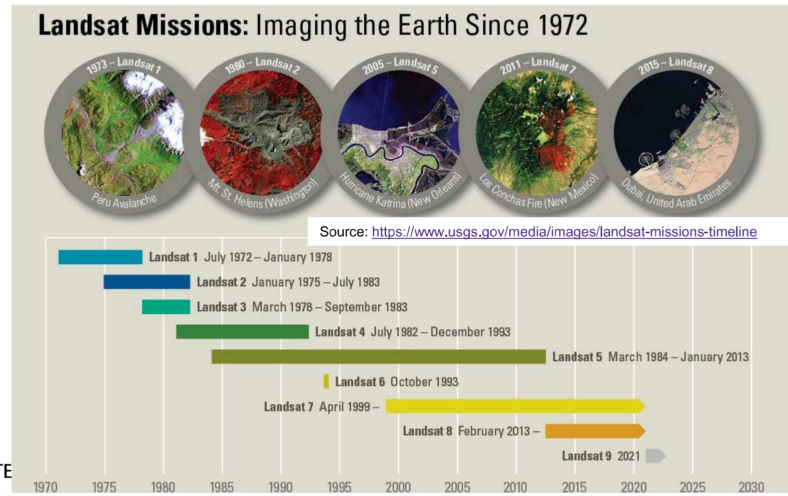
Long term planning and data provision consistency by ESA and EUMETSAT (also MSG, METOP and JASON)
See also future planned launches at:
https://space.skyrocket.de/



MISSIONS OVERVIEW: LANDSAT

Failures of missions are compensated by extending the life of other missions. Landsat 5 was an exceptional case.
Its original mission was 3 years. A failure in LandSat 6 required to extend its life expectancy, which covered well beyond the launch of Landsat 7.

Without fuel to keep the orbit it was lowered, shut down and decommissioned in 2013 one month before the launch of Landsat 8, but it is still orbiting Earth till it reenters the atmosphere around 2034.

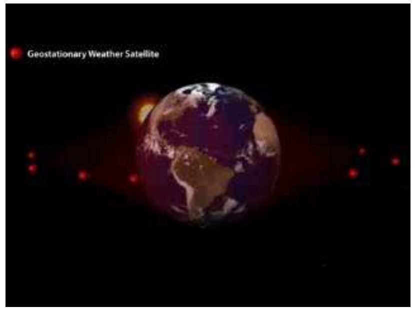


Source: https://www.usgs.gov/media/images/landsat-missions-timeline

ORBIT CHARACTERISTIC: ALTITUDE

- **Low earth orbits (LEO)**
  - Altitude 180-2000 km; e.g. spy satellites, space shuttle and most satellites for EO
- Medium Earth Orbit (MEO)
  - Altitude 2000-35750 km; e.g. Navigation
- High Earth Orbit (HEO)
  - Altitude >35750 km; e.g. geostationary

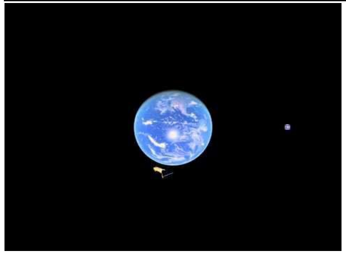
Polar orbiting satellites are closer than 35750 km of altitude



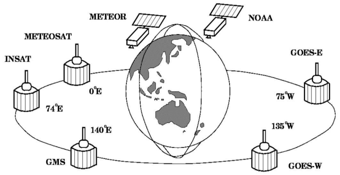
https://www.youtube.com/watch?v=FsfclEmR_b0

https://earthobservatory.nasa.gov/features/OrbitsCatalog

GEO STATIONARY ORBITS



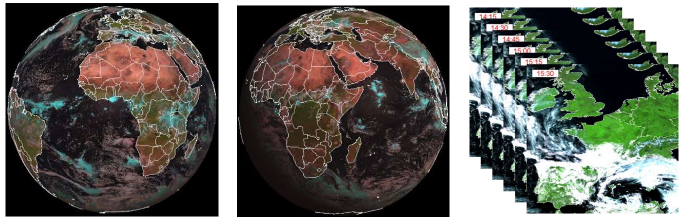
https://www.youtube.com/watch?v=lrxg-9svRtc



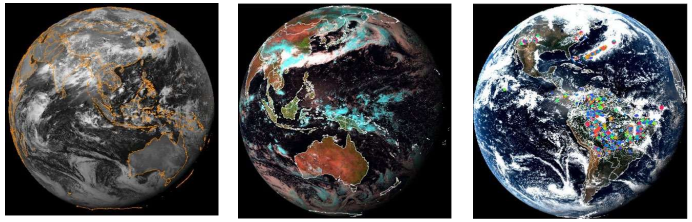
- Relative position to Earth is fixed
- Hemispherical distorted view
- Easy geo-referencing
- Coarse resolution due to distance. (Getting better by reducing IFOV)

- Meteorological weather systems use a combination of polar (HR) and geostationary (LR) satellites.

GEO STATIONARY CONSTELLATION - EXAMPLES



MSG satellites (at 0° and 45.5°) and time series with 15 minutes interval

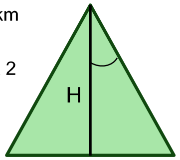


Fengyun, Himawari-8 and GOES-East with GLM

ORBIT AND FIELD OF VIEW (FOV) SATELLITE

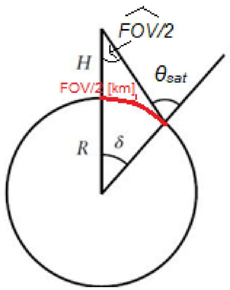
- Satellite field of view (FOV) and height determine how much a satellite can see.
- For quantitative remote sensing there is limitation of satellite zenith angle θ_{sat} (θ_{sat_max} = 60°)
- Thus for geostationary satellite maximum FOV = 11.800 km

- For narrow FOV/flat terrain: FOV [km] = tan(FOV/2) x H x 2



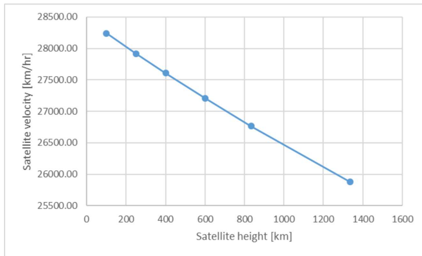
For wide FOV compensate for earth curvature : FOV [km] =2 R [km] (δ° π/180°).

For AVHRR with θ_{sat_max} = 60° and H = 840km the FOV = 2227 km



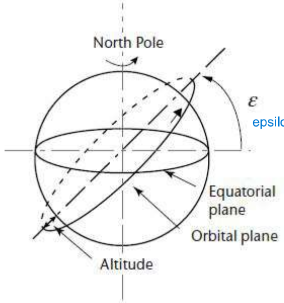
ORBIT CHARACTERISTIC: ALTITUDE VERSUS VELOCITY

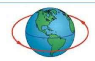
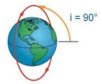
- Satellites travel fast, at a height of 35786 km the forward movement of the satellite, from west to east direction and in equatorial plane is in sync with the earth rotation
- The higher the satellite the lower the velocity
- SunSync EO satellites orbiting at about 700 km travel at 7 km/s (approx). Implications?



ORBIT CHAR: INCLINATION ANGLE

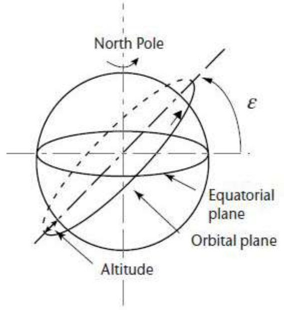
- Angle between orbital plane and equator
- Determines which latitudes are measured, e.g. Jason-3 at 66° and GPM at 65°
- Polar orbit inclination between 80° and 100°. Implications?

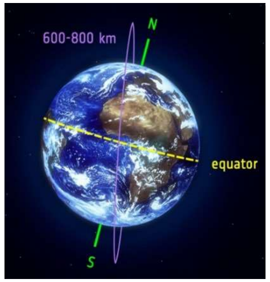


Inclination	Orbital Type	Diagram
0° or 180°	Equatorial	
90°	Polar	 i = 90°
0° ≤ i < 90°	Direct or Prograde (moves in the direction of Earth's rotation)	 ascending node
90° < i ≤ 180°	Indirect or Retrograde (moves against the direction of Earth's rotation)	 ascending node

ORBIT CHAR: INCLINATION ANGLE

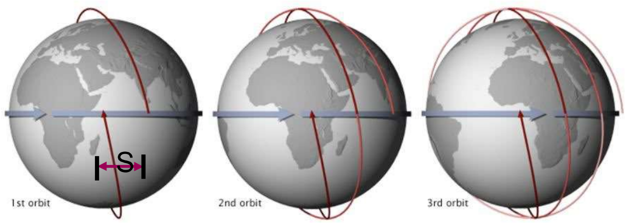
- Special polar orbit: Sun Synchronous Orbit (SSO) , inclination about 98,5°
- A nearly polar orbit around the Earth, in which the satellite passes over any given point of the planet's surface at the same local mean solar time (mostly between 09:30 to 10:30 am)
- Implicatio





ORBIT CHAR: ORBIT STEP

- Orbit step (S) is next overpass at equator upon completion of another orbit (distance)
- Orbit step, together with FOV – zenith angle, determine how long it takes to get global coverage

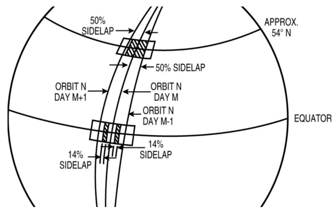


- In SSO, at 800 km, swath with of 2800 km, slightly more than 14 orbits: daily global coverage

ORBIT CHAR: PERIOD & REPEAT CYCLE

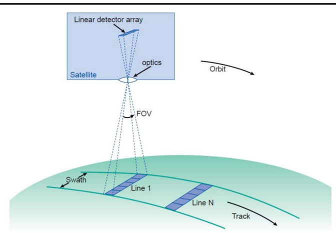
- Period: Time to complete one full orbit (360 degrees rotation)
- Repeat cycle: Time between two successive identical orbits
- Revisit time: Time between two subsequent images of the same area

https://www.youtube.com/watch?v=y_jM_BxQGvE

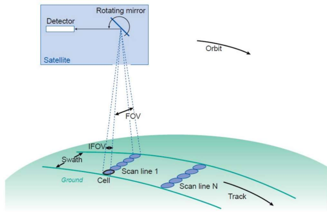


SENSOR CLASSIFICATION (HOW THEY OPERATE)

- Cameras (many 'pixels' at a time)
  - CCD (detector array)
    - Line (camera or push broom)
    - Array (camera)



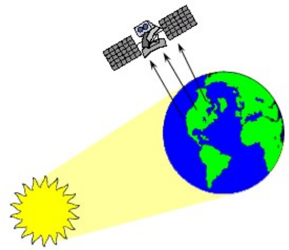
- Scanners (single 'pixel' at a time)
  - Whiskbroom (ind. detectors)
  - Multiple sensors/bands



SENSOR CLASSIFICATION BASE ON SOURCE

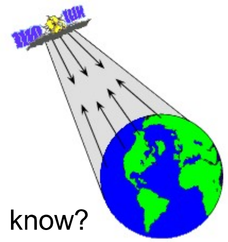
Passive Sensors

- Source of radiation is external
  - Solar reflected radiation (SW)
  - Emission from Earth (LW)
  - Emission from Atmosphere (LW)



Active Sensors

- Emits radiation towards a target. Partly is reflected to the sensor energinya kecil, makanya dia butuh nembak supaya memperbesar energi
  - Radar radio detection and ranging
  - Lidar



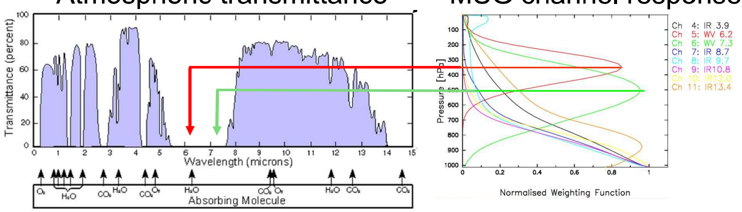
Any other you know?

https://www.nrcan.gc.ca/maps-tools-publications/satellite-imagery-air-photos/remote-sensing-tutorials/introduction/passive-vs-active-sensing/14639

SENSOR CLASSIFICATION (WHAT SOURCE) VIP

1. Surface sensing with no contribution from atmosphere (passive). We are interested in the surface
2. Atmospheric sensing, when there is no contribution from the surface (passive). We are interested in the atmosphere.
3. Sensing when there is no contribution from surface emission or atmosphere (active), from 2 cm – 10 m wavelength. Active RS do not require other source.

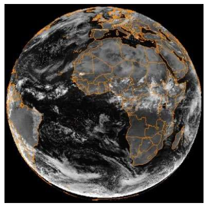
Atmospheric transmittance | MSG channel response



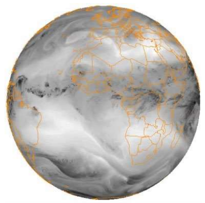
Weighting function describes the width and the weight of layer of the atmosphere from which the radiation measured by a particular satellite channel was emitted (atmospheric sensing or surface sensing)

SENSOR / INSTRUMENT – IMAGE CHARACTERISTICS VIP

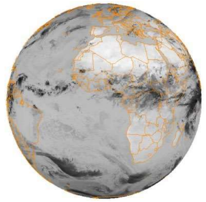
Resolutions/Characteristics:	Example MSG:
Spectral	11 spectral channel and 1 HRV
Spatial	3 km sub-satellite and 1 km sub satellite
Temporal	every 15 minutes
Radiometric	10 bits



MSG Vis 0.8



WV 06.2



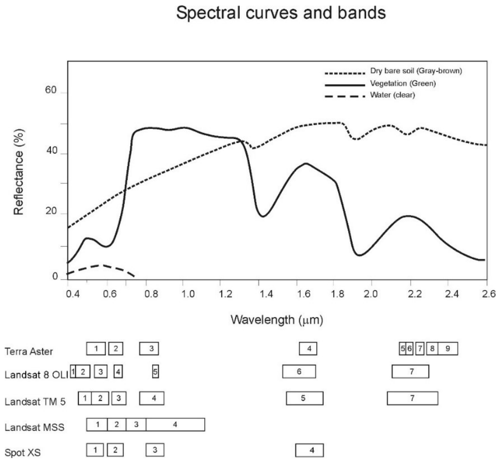
TIR 10.8 micron

SPECTRAL CHARACTERISTIC

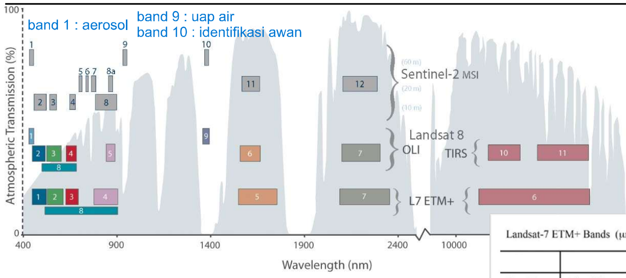
Answers to…

- How many bands?
- How narrow/wide?

- Location/range of bands in EM spectrum



SPECTRAL CHARACTERISTICS LANDSAT 7/8 & SENTINEL 2

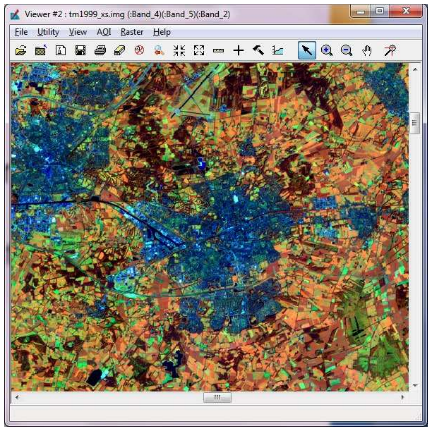


http://eros.usgs.gov/sentinel-2

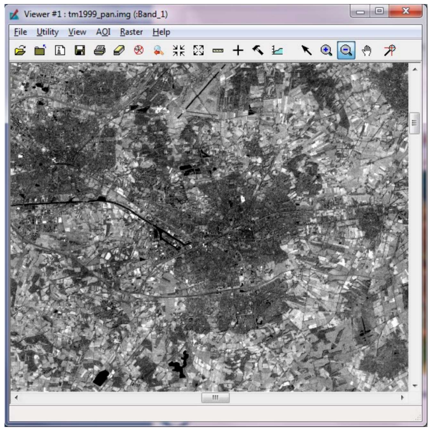
Landsat-7 ETM+ Bands (μm)			Landsat-8 OLI and *TIRS* Bands (μm)		
			30 m Coastal/Aerosol	0.435 - 0.451	Band 1
Band 1	30 m Blue	0.441 - 0.514	30 m Blue	0.452 - 0.512	Band 2
Band 2	30 m Green	0.519 - 0.601	30 m Green	0.533 - 0.590	Band 3
Band 3	30 m Red	0.631 - 0.692	30 m Red	0.636 - 0.673	Band 4
Band 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

EXAMPLES – SPECTRAL CHAR.

Landsat -4



ETM 4,5,2 NIR 1, NIR 2, green

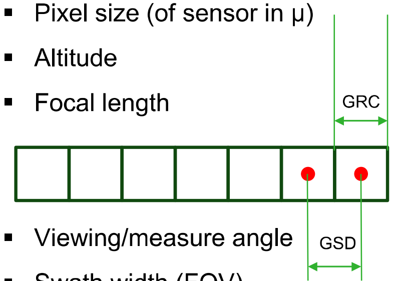


ETM Pan

SPATIAL CHARACTERISTICS - RESOLUTION

Camera

- Pixel size (of sensor in μ)
- Altitude
- Focal length

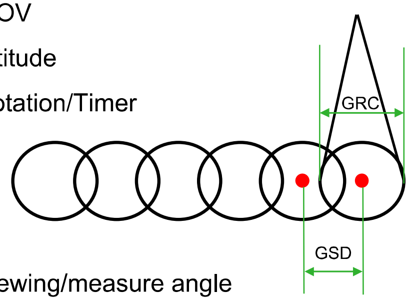


- Viewing/measure angle
- Swath width (FOV)
- Ground Resolution Cell GRC

= Ground Sampling Distance GSD

Scanner

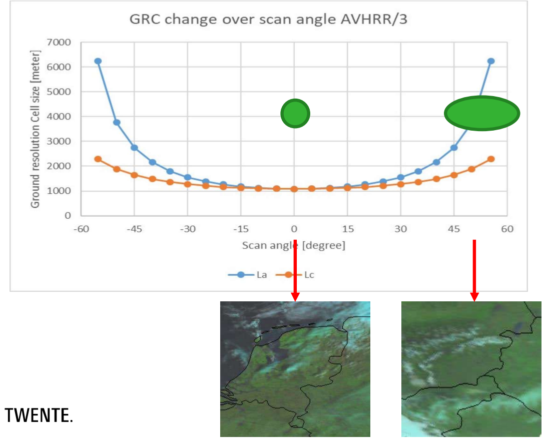
- IFOV
- Altitude
- Rotation/Timer



- Viewing/measure angle
- Swath width (FOV)
- GRC <> GSD

SPATIAL CHARACTERISTICS - RESOLUTION

- Scanner along & across track resolution as a function of viewing angle – AVHRR-3



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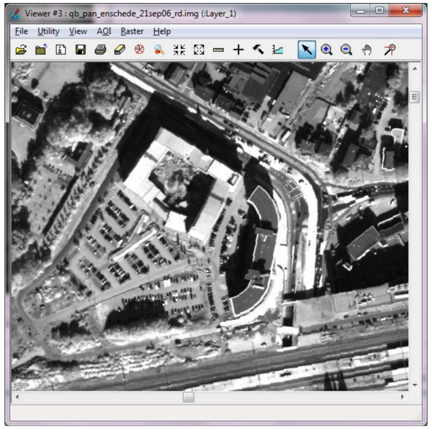
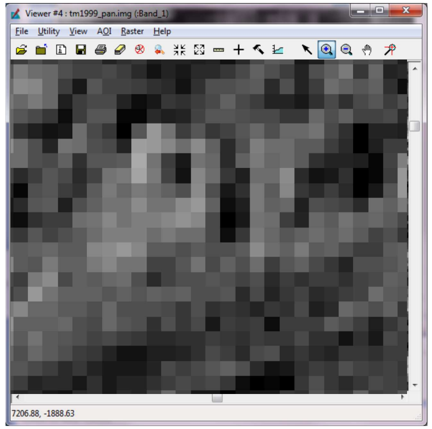
EXAMPLE – SPATIAL RESOLUTION





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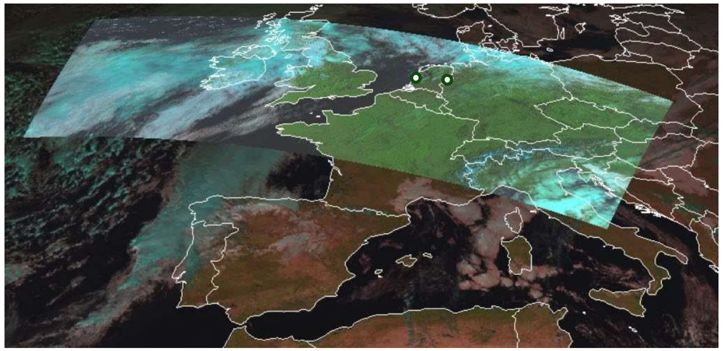
QB PAN

ETM PAN

SPATIAL COVERAGE

- MSG and AVHRR (3 minutes scan)



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RADIOMETRIC CHARACTERISTICS

A sensor measures radiance in a range (dynamic range).

Too little = no measurement

Too much = saturation

Dynamic range: [Minimum, Maximum] intensity watt/m^2/sr

Within the range the sensor has a precision… 1, 2.. Decimals

With the dynamic range and the precision, a quantization is defined. The higher the more precise.

AD conversion and quantization

Radiometric resolution [min, max] DN, #bit (~precision)

Effective radiometric resolution is combination of both

34.1 <=Range <= 42.0
I need to measure 79 values.
My instrument is unable to read more than with 0.1°C precision.

The real measurement is 39.62 °C

1 bit= 2^1= 2
2 bits= 2^2= 4
3 bits= 2^3= 8
4 bits= 2^4= 16
5 bits= 2^5= 32
6 bits= 2^6= 64
7 bits= 2^7= 128
8 bits= 2^8= 256
…
16 bits= 2^{16}= 65536

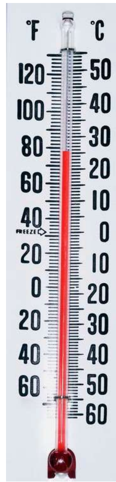
Quantization to 7
Sensor records 39.6 because is unable to measure 39.62

-61 <=Range <= 55
I need to measure 116 values because my instrument can read with a precision of 1°C.

The real measurement is 25.7 °C

1 bit= 2^1= 2
2 bits= 2^2= 4
3 bits= 2^3= 8
4 bits= 2^4= 16
5 bits= 2^5= 32
6 bits= 2^6= 64
7 bits= 2^7= 128
8 bits= 2^8= 256
…
16 bits= 2^{16}= 65536

Quantization to 7
Sensor records 26 because is unable to measure 25.7



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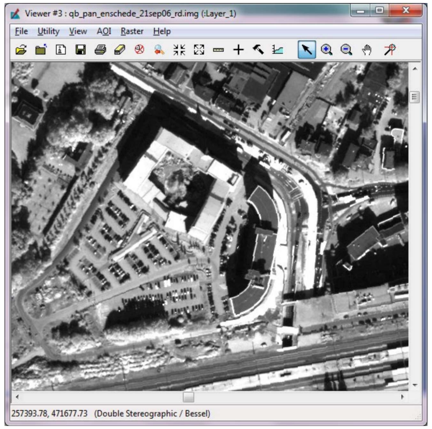
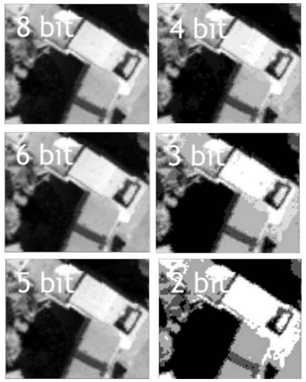
EXAMPLE: RADIOMETRIC CHARACTERISTICS



QB 21 Sep 2006 (11 bit)



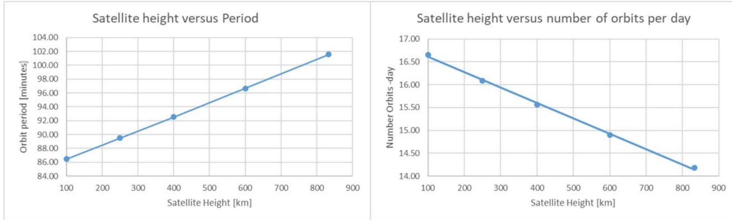
What does 1 bit data look like?

$$8bit = 2^8 = 256\ DN$$

TEMPORAL CHARACTERISTICS

- Repeat cycle; time between two identical overpasses
- Revisit time; time between two acquisitions of the same area

Period and number of orbits as function of satellite height

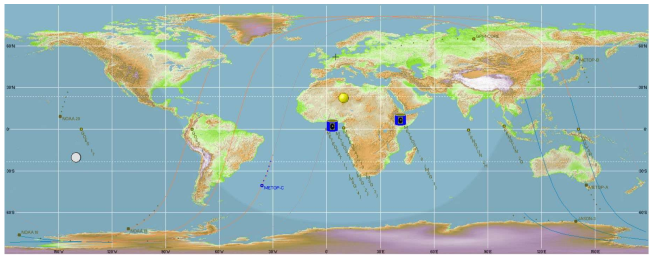


(REAL TIME) DATA PROVISION

- From satellite observation to availability "on the ground" requires ground stations, eventually by a Data Relay System and further data pre-processing by satellite data provider

DEMO-1: SATELLITE TRACKING

- Real time orbit tracking: https://www.satsignal.eu/software/wxtrack.htm



- Historical polar orbit tracks:

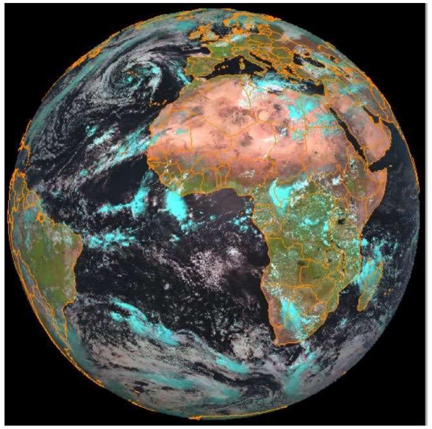
SSEC Space Science and Engineering Data Center

https://www.ssec.wisc.edu/datacenter/polar_orbit_tracks/

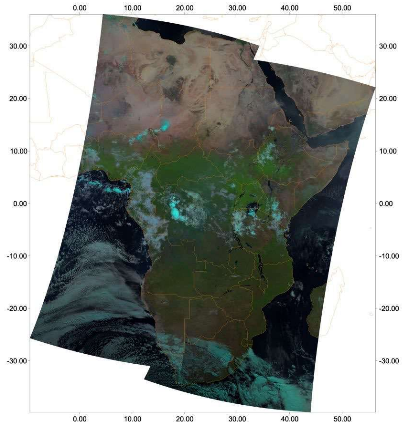
Other: https://sourceforge.net/projects/previsat/

DEMO-2: (REAL TIME) DATA VISUALIZATION

Example: GEONETCast delivered MSG and AVHRR data



Simulated MTG image

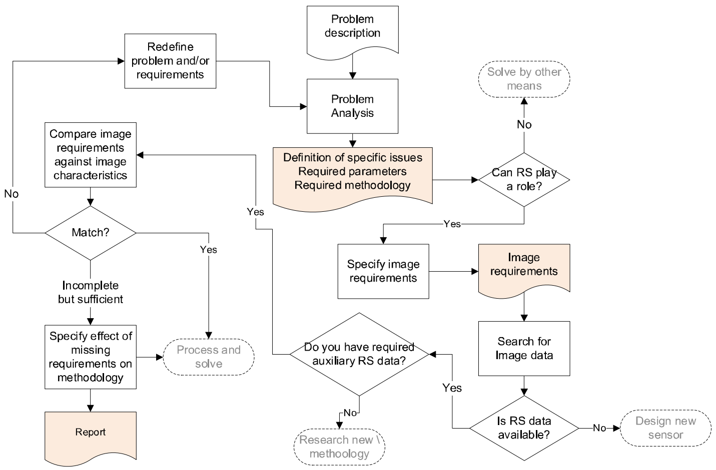


2 orbit strips over Africa, early morning, 6 segments of 3 minutes each / orbit

DEMO-3: GOOGLE EARTH ENGINE

Or install the Python API

DISCUSSION: INSTRUMENT–IMAGE SELECTION WORKFLOW



Questions

Add them in the discussion board