optical (and infrared) remote sensing basics

UNIS Glaciology Course

vår 2017

Today's Topics

- electromagnetic radiation
- interaction of emr with objects
- spectral properties of snow and ice
- types of sensors and satellite missions
- accessing data

reminder: what is remote sensing?

- "acquisition of information about an object or phenomenon without direct contact"
- in practice, we use some form of electromagnetic radiation
- generally speaking, remote sensing is shorthand for observations from satellites
- passive vs active sensors
- reflected vs emitted radiation

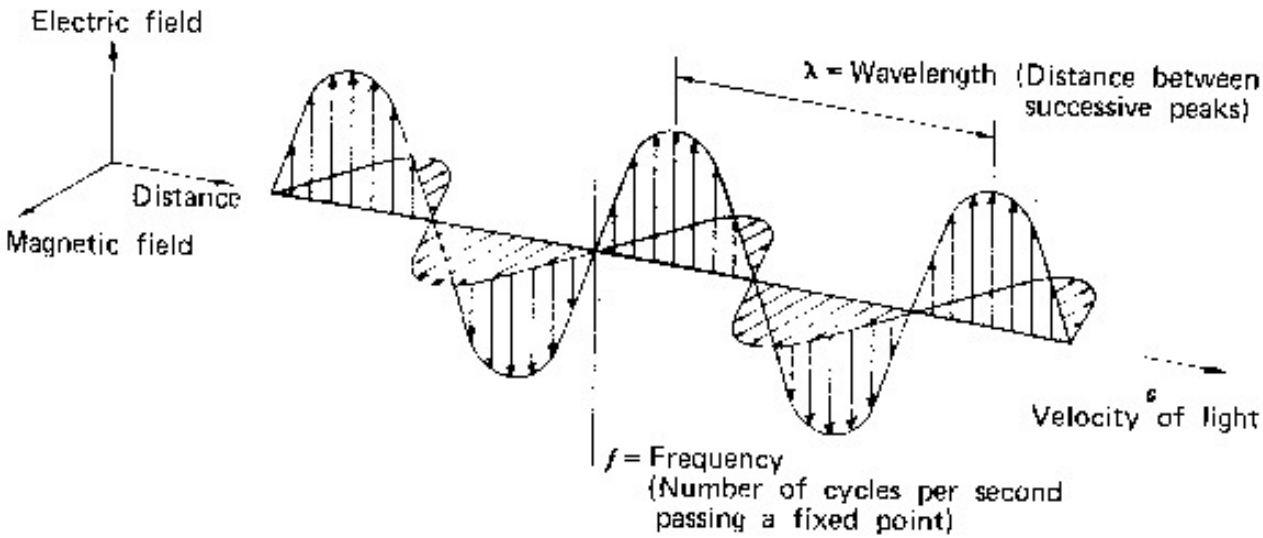
electromagnetic radiation

- electromagnetic radiation (light) behaves as both a wave and a particle (photon)
- can use the Planck-Einstein equation to describe the energy of a photon:

$$E = h\nu = \frac{hc}{\lambda}$$

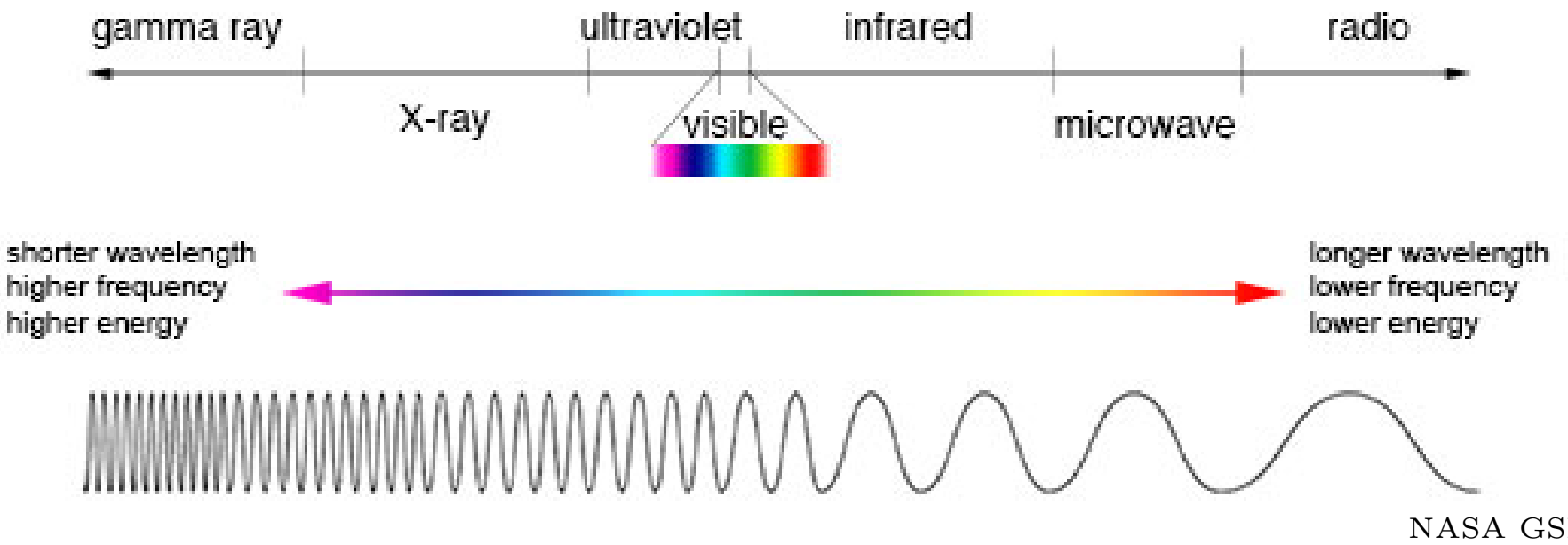
- wavelength (λ), frequency (ν) provide fundamental information about how em radiation interacts with objects

electromagnetic radiation



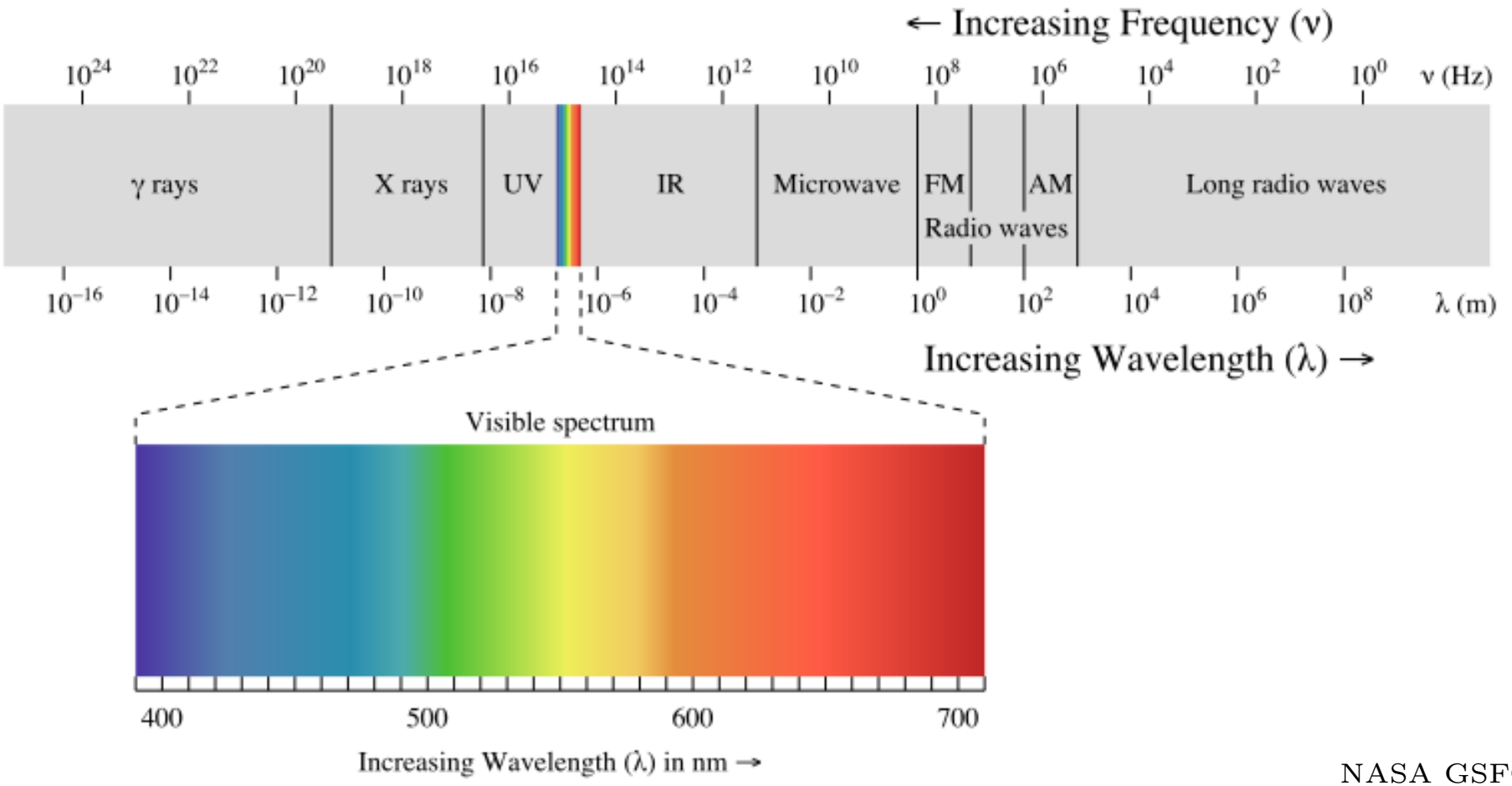
UN FAO

the electromagnetic spectrum



NASA GSFC

the electromagnetic spectrum



NASA GSFC

the electromagnetic spectrum

the wavelengths we use for remote sensing (of earth):

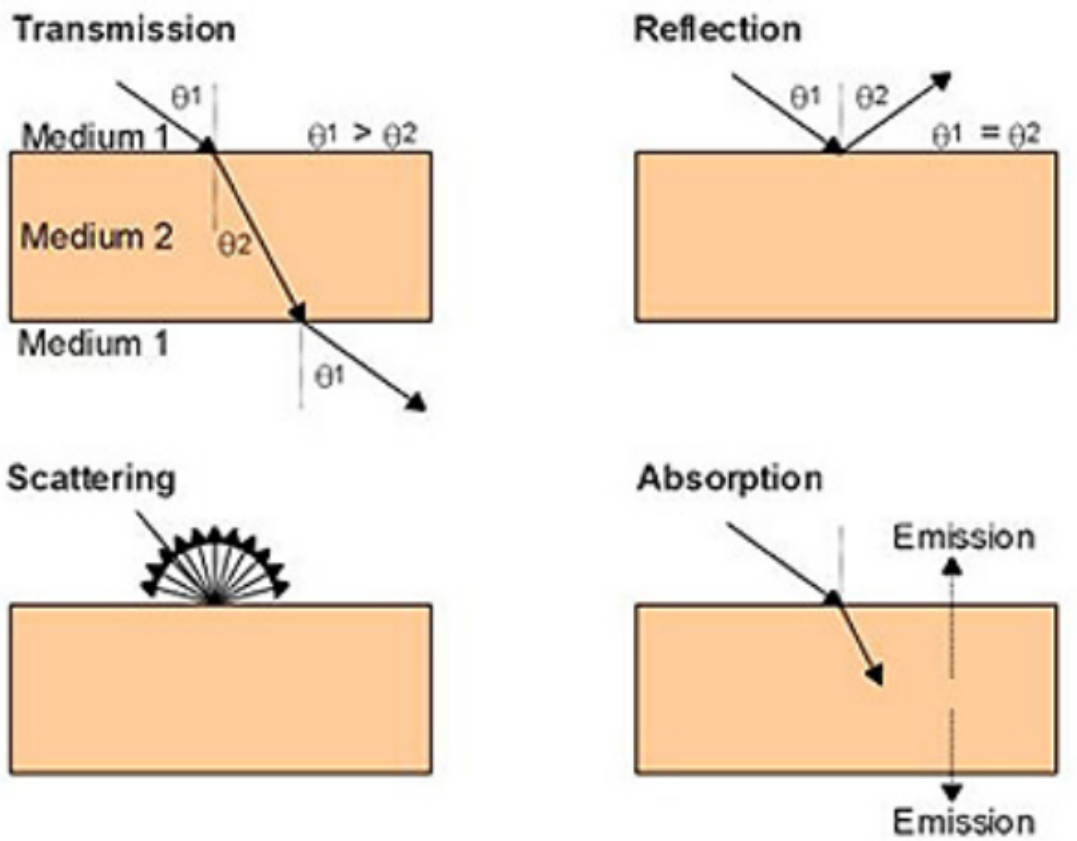
- visible light: 0.4 - 0.7 μm
- near infrared (NIR): 0.7 - 0.8 μm
- shortwave infrared (SWIR): 3 - 5 μm
- thermal infrared (TIR): 8 - 14 μm
- far-infrared: 15 - 1000 μm
- microwave: 1 - 1000 mm

electromagnetic radiation interacts with things

when emr interacts with an object (or medium), we have three possibilities:

- radiation is transmitted
- radiation is absorbed
- radiation is reflected
- reflection can be specular or diffuse (scattering)

electromagnetic radiation interacts with things



NASA GSFC

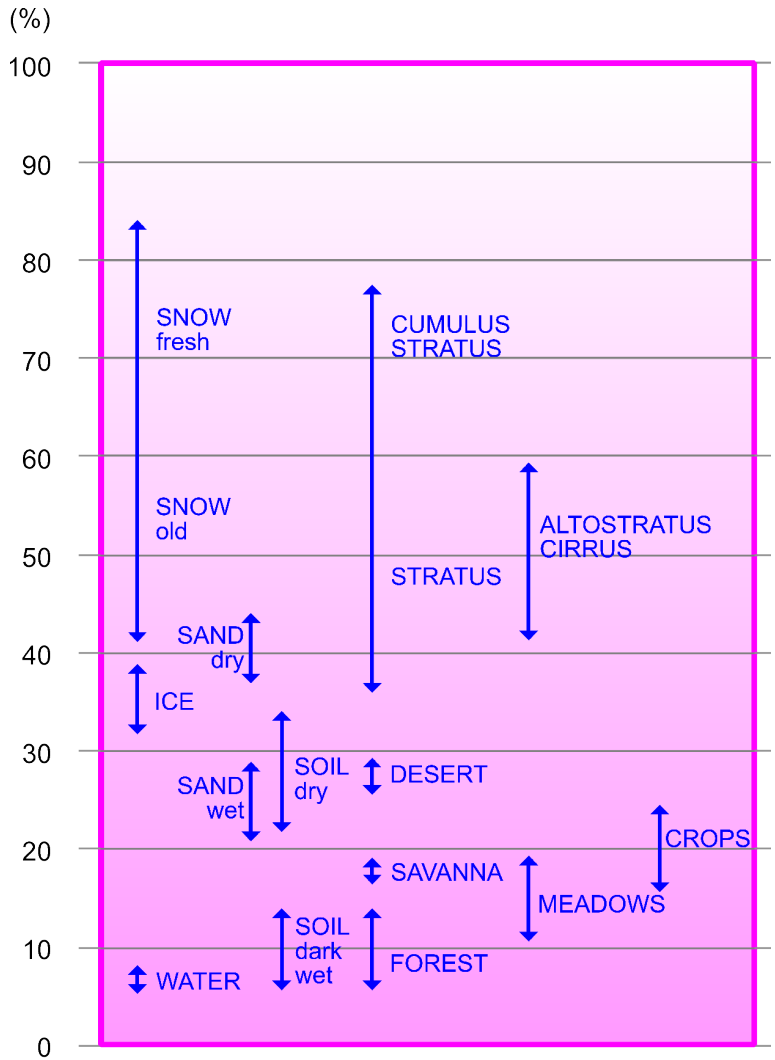
bi-directional reflectance distribution function

- most objects behave as something between specular and diffuse (Lambertian) reflectors
- reflectance is based on properties of material, radiation, as well as viewing and illumination angles
- the bi-directional reflectance distribution function (brdf) describes ratio of the reflected radiation to the incident radiation, for a given wavelength, incidence angle, reflectance angle and azimuth
- to measure in practice from a satellite, need multiple sensors with multiple viewing angles or ability to change angle

albedo

- albedo is the ratio of total reflected radiation by a surface to the total incident radiation (both direct and diffuse)
- the brdf integrated over the whole viewing hemisphere
- two components: direct and diffuse
- dependent on atmospheric state (i.e., not an intrinsic property of the surface)
- dependent on wavelength of incoming radiation

typical albedo values (visible light)



earth's atmosphere

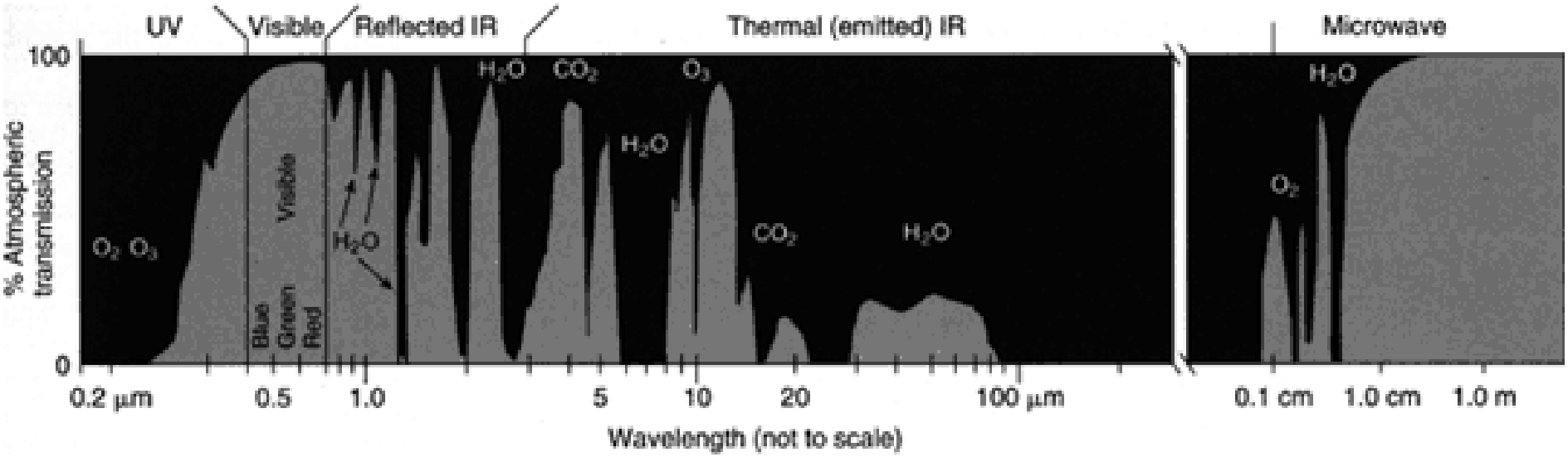
- earth's atmosphere is composed of nitrogen, oxygen, water vapor, carbon dioxide, ozone, other trace gases
- these molecules absorb photons (electromagnetic radiation) at particular wavelengths
- non-absorbed radiation is transmitted
- even if it's not absorbed, it can still be scattered (reflected)

scattering

three types of atmospheric scattering, depending on wavelength of radiation and size of scatterer

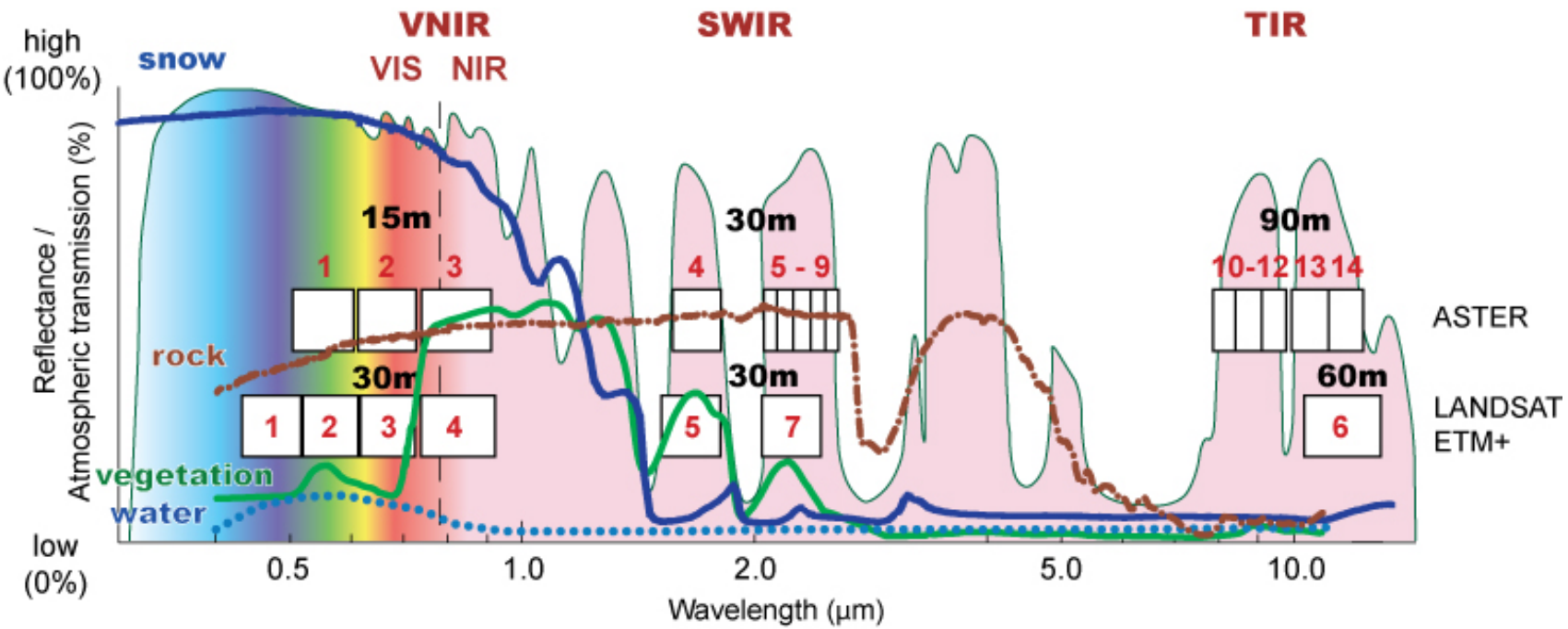
- Rayleigh scattering: particle size $\ll$ wavelength
  - this is why the sky is blue (also biology)
  - also why sunsets are red/orange, sun appears yellow
  - most common form of scattering
- Mie scattering: particle size $\approx$ wavelength
  - water vapor, smoke, fumes, dust
  - causes diffuse illumination
  - red sky from forest fires, volcanic eruption
- non-selective scattering: particle size $\gg$ wavelength
  - dust, water vapor (clouds)
  - tends to affect visible, NIR and mid-IR equally

atmospheric windows



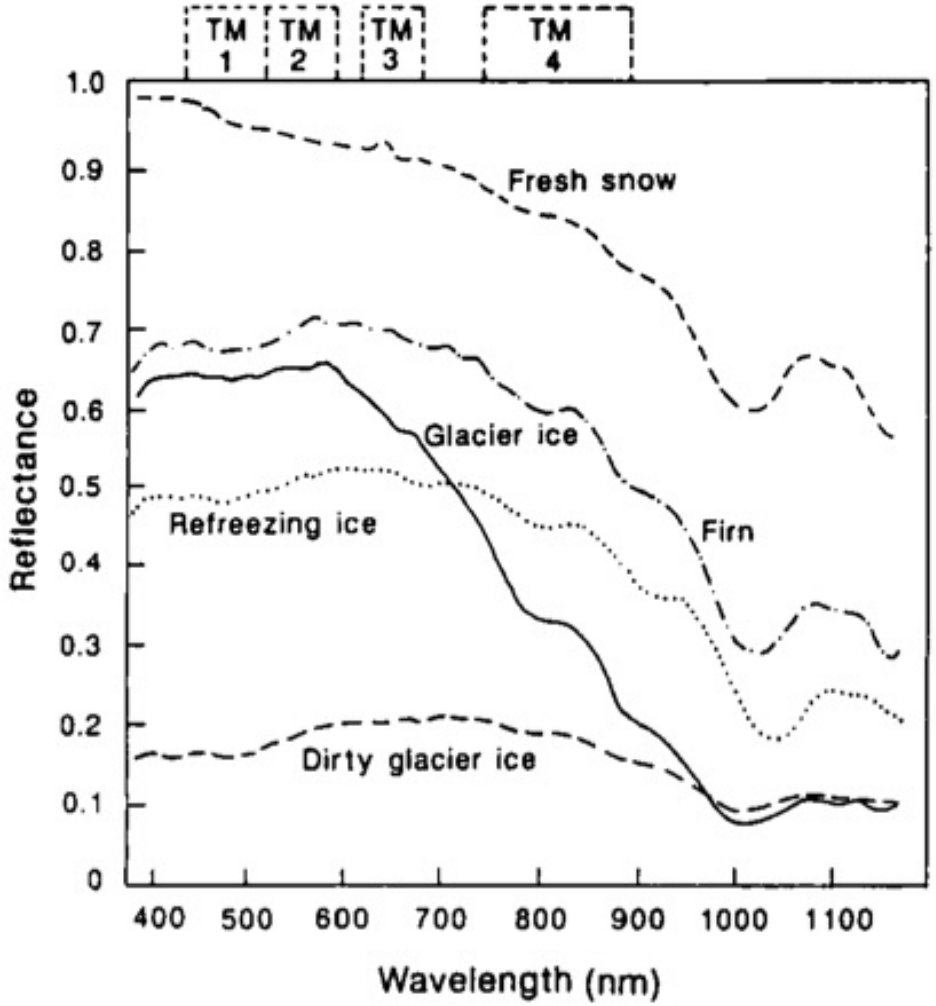
(NASA Earth Observatory)

spectral signatures of common materials



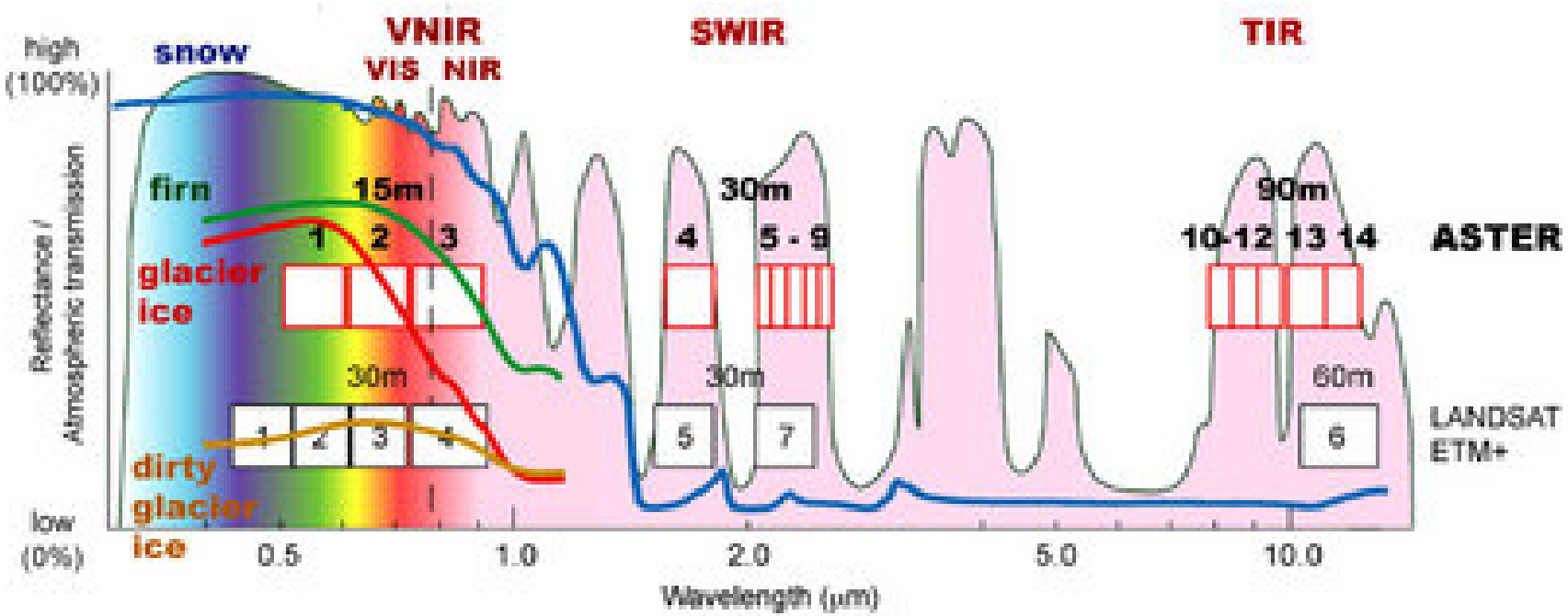
(A. Kääb)

spectral signatures of snow/ice



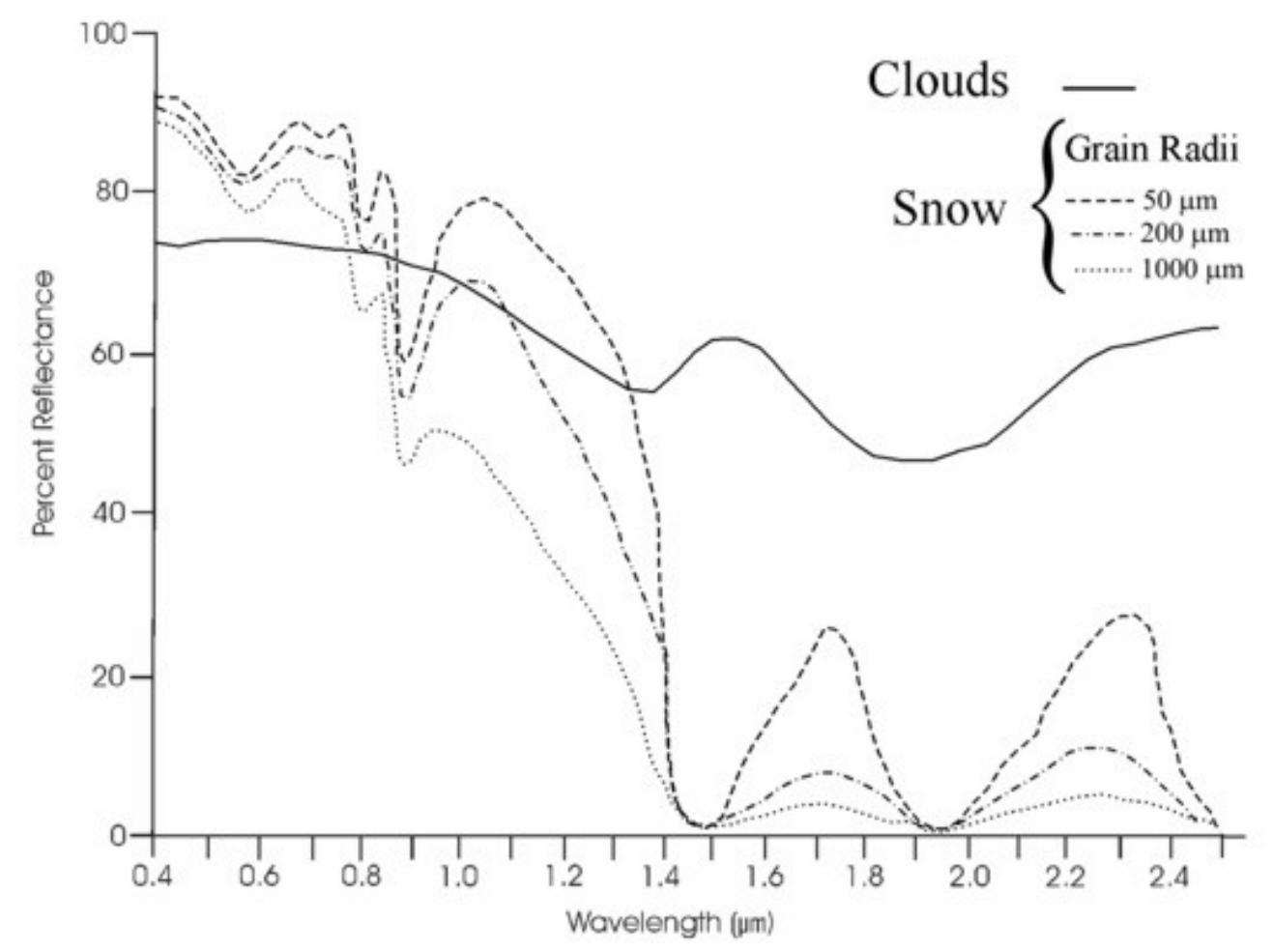
(Winther, 1993)

spectral signatures of snow/ice

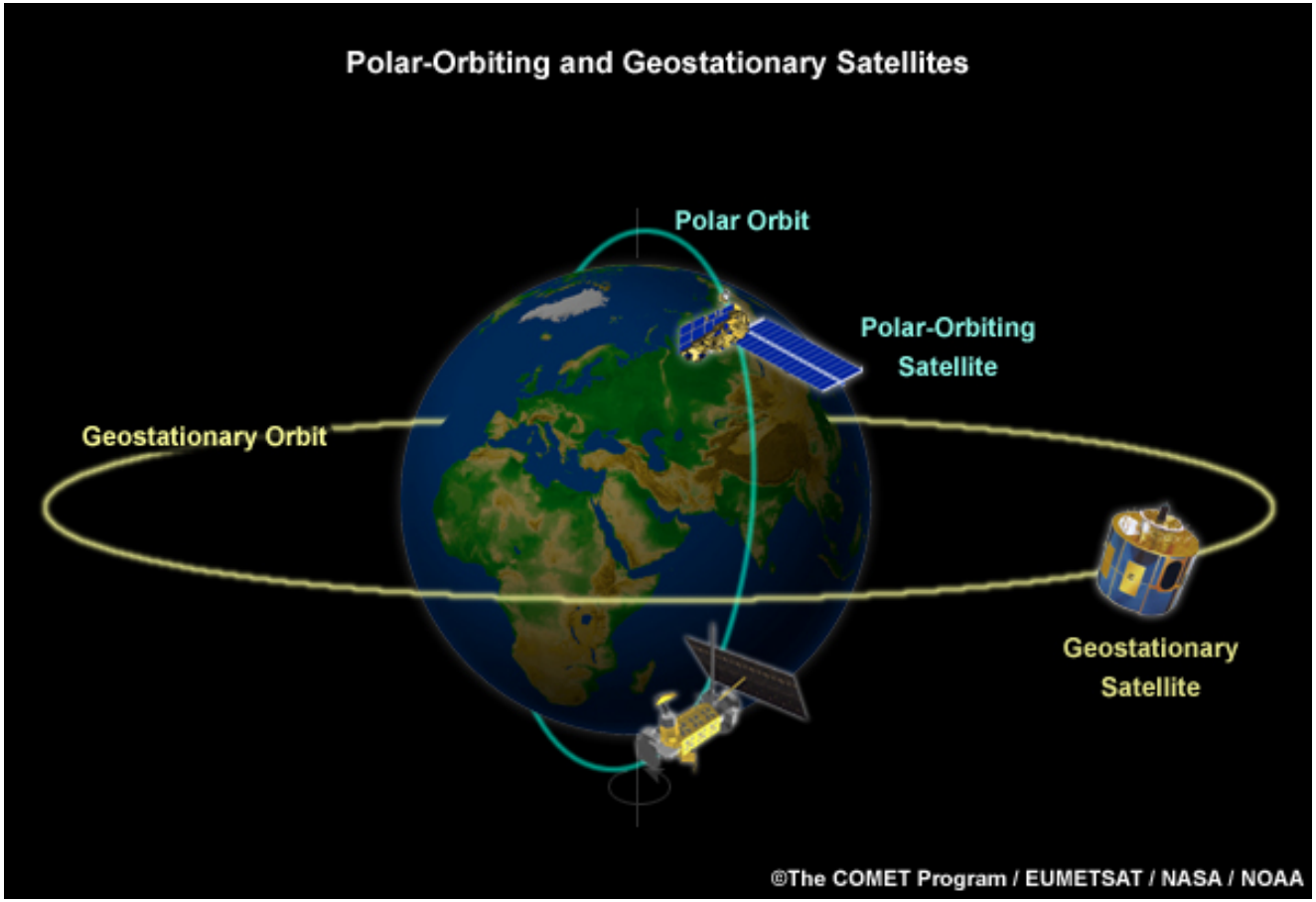


(A. Kääb)

spectral signatures of snow and clouds



satellite orbits



satellite orbits

- geosynchronous orbits:
  - ∼35,800 km, about 1/10th the distance between earth and moon
  - results in a period of ∼24 hours
- polar orbits:
  - typically ∼700-800 km, period of ∼100 minutes
  - usually choose sun-synchronous orbit
  - orbit must precess throughout the year, so orbital plane must be inclined from pole

swaths and repeat coverage

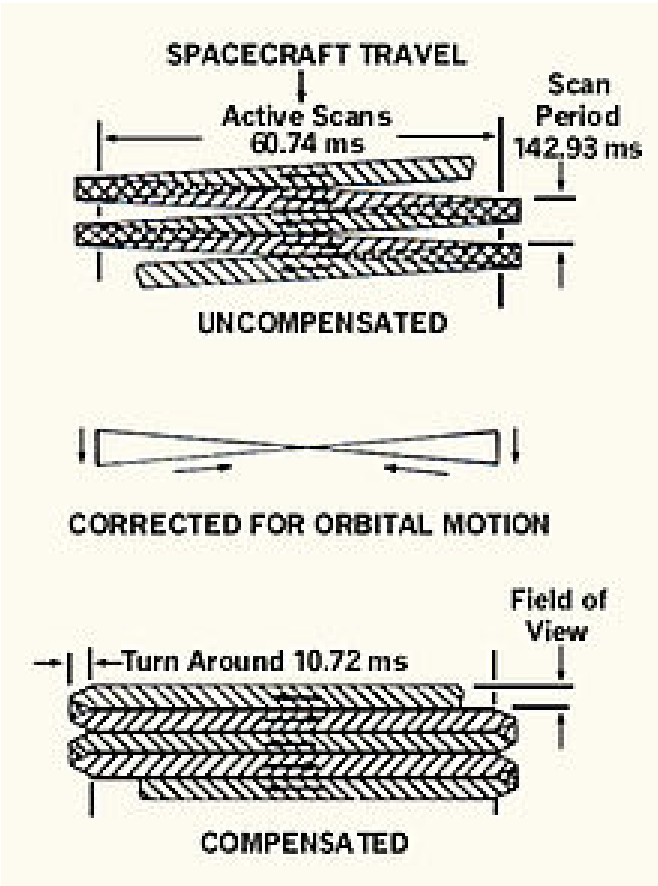
- amount of the earth's surface covered by an overpass is called swath width
- this depends on the sensor, orbit height

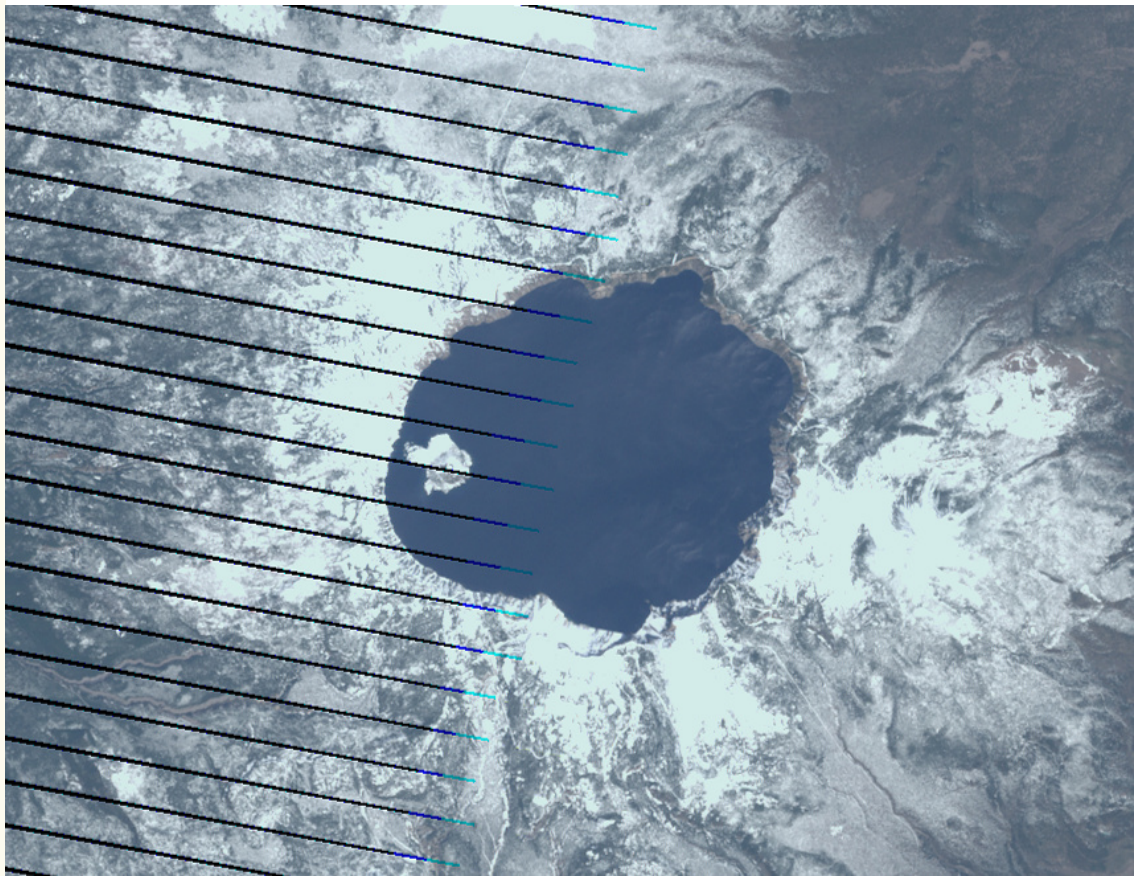
brooms

to increase sensor coverage in a given overpass, have two options:

- can move the sensor: whisk-broom scanner
- can mount multiple sensors in an array: push-broom

brooms


SPACECRAFT TRAVEL
Active Scans
60.74 ms
Scan
Period
142.93 ms
UNCOMPENSATED
CORRECTED FOR ORBITAL MOTION
Field of
View
←Turn Around 10.72 ms
COMPENSATED



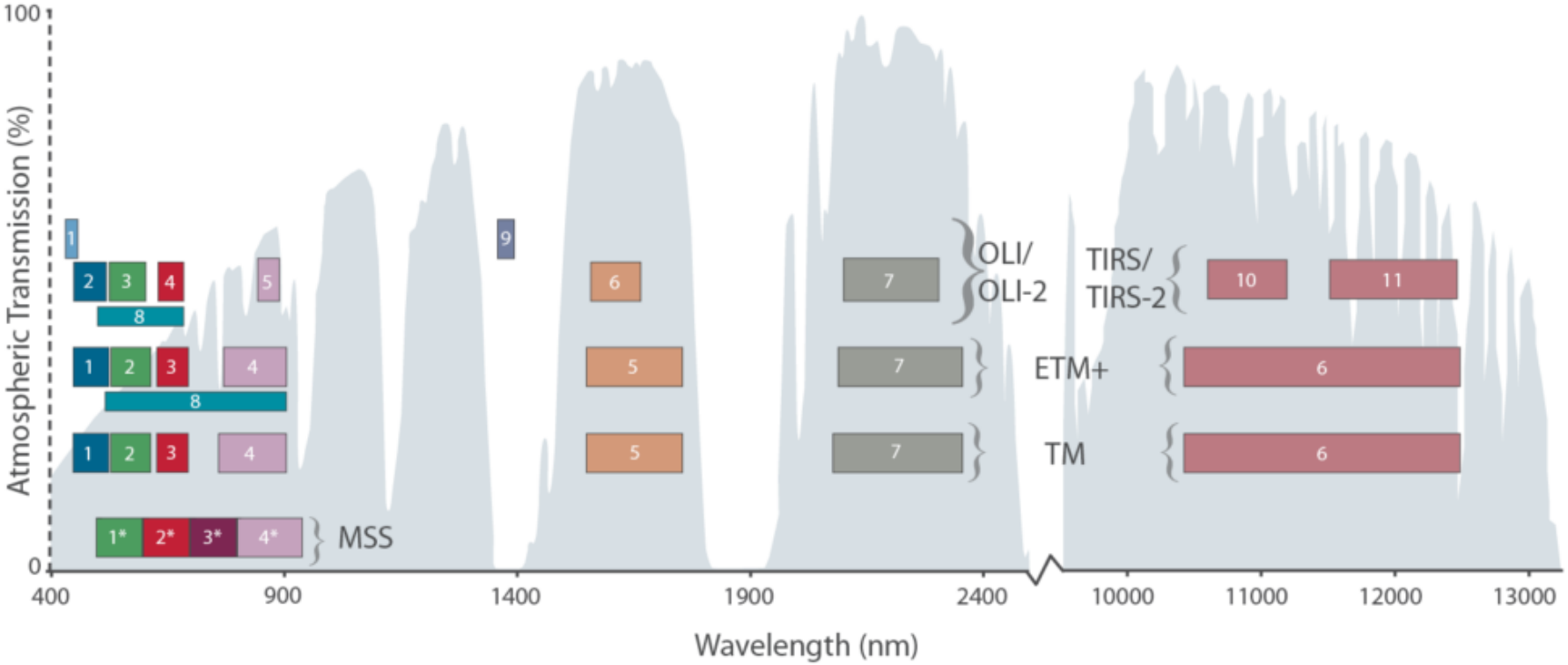
a word on resolution

- spatial resolution: ability to distinguish/separate targets
- spectral resolution: ability to distinguish between different wavelengths
- temporal resolution: time between repeat observations
- radiometric resolution: precision of observations

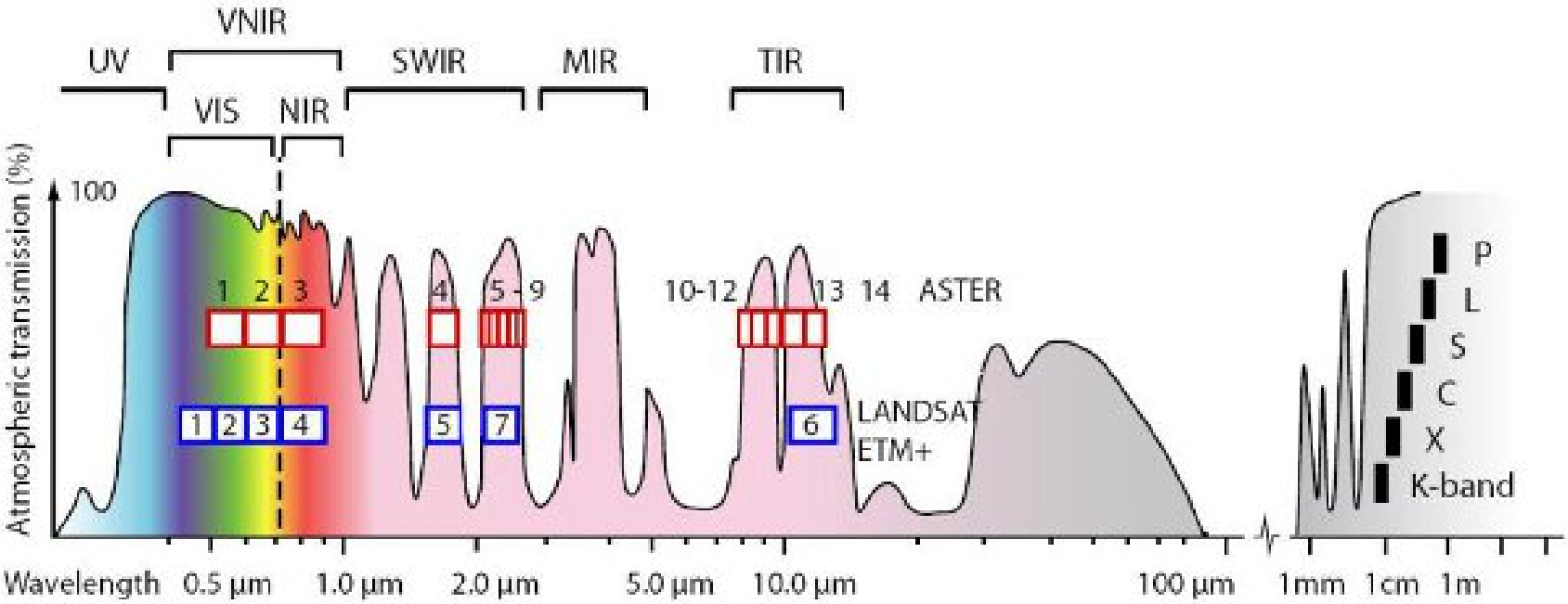
the landsat program

- Landsat 1 (1972-1978), Landsat 2 (1975-1982), Landsat 3 (1978-1983): multi-spectral sensor (mss)
- Landsat 4 (1982-1983), Landsat 5 (1984-2013(!)): mss and thematic mapper (tm)
- Landsat 7 (1999-): enhanced thematic mapper plus (etm+)
- Landsat 8 (2013-): operational land imager (oli) and thermal infrared sensor (tirs)

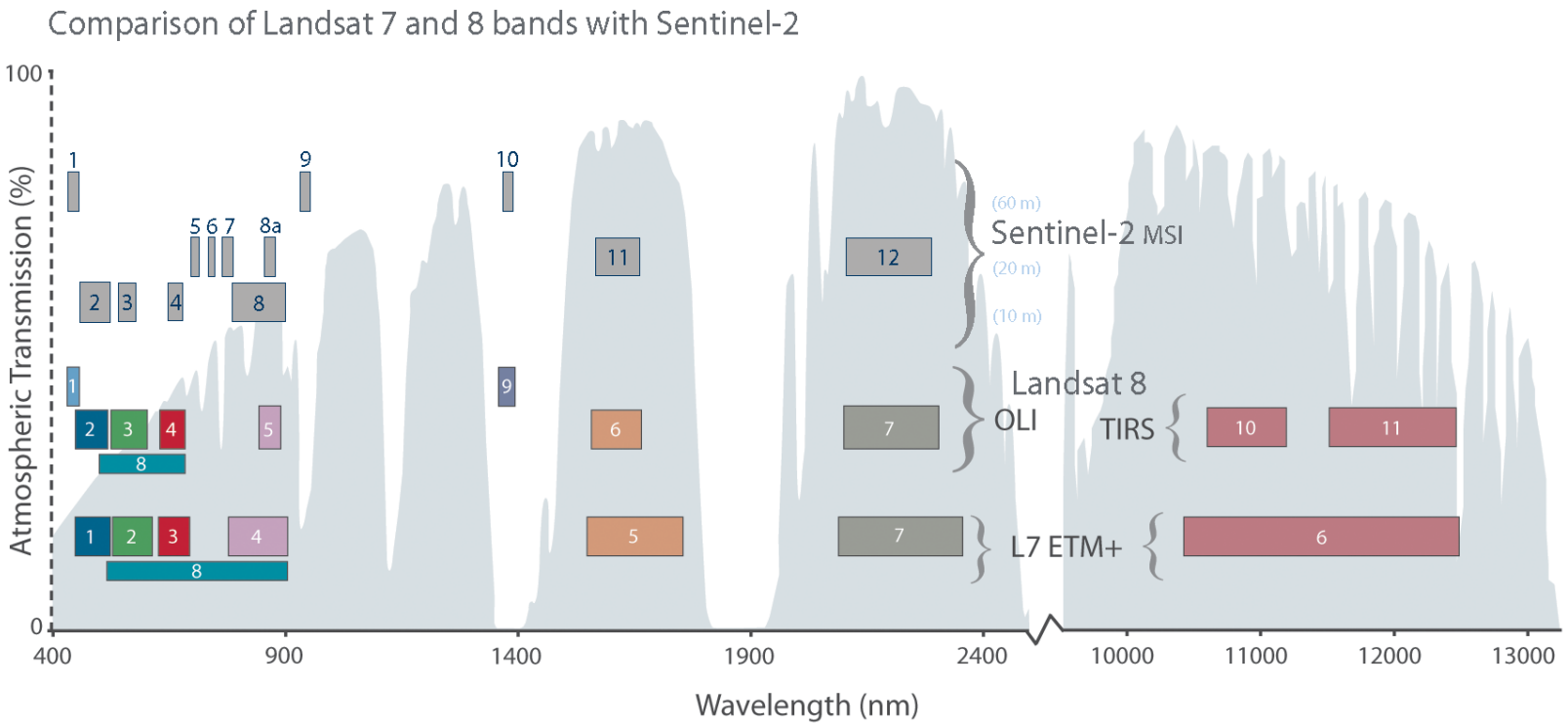
the landsat program



aster


VNIR
UV
SWIR
MIR
TIR
VIS
NIR
Atmospheric transmission (%)
100
1 2 3
4
5 - 9
10-12
13 14
ASTER
1 2 3 4
5
7
6
LANDSAT
ETM+
P
L
S
C
X
K-band
Wavelength
0.5 µm
1.0 µm
2.0 µm
5.0 µm
10.0 µm
100 µm
1mm
1cm
1m

sentinel-2


Comparison of Landsat 7 and 8 bands with Sentinel-2
Atmospheric Transmission (%)
100
0
400
900
1400
1900
2400
10000
11000
12000
13000
Wavelength (nm)
(60 m)
Sentinel-2 MSI
(20 m)
(10 m)
Landsat 8
OLI
TIRS
L7 ETM+

commercial sensors

- satellite pour l'observation de la terre (spot)
- pléiades
- worldview
- quickbird
- ikonos
- planet labs

data access

- landsat, aster: nasa reverb (`https://reverb.echo.nasa.gov/`)
- landsat: can also use usgs earth explorer (`http://earthexplorer.usgs.gov`)
- sentinel-2: copernicus open access hub (`https://scihub.copernicus.eu/`)
- sentinel-2: can also use amazon web service

questions?