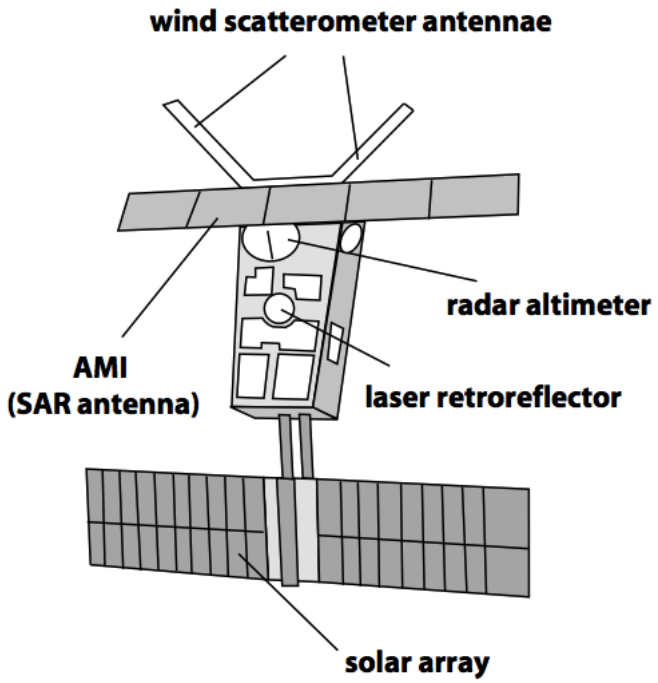
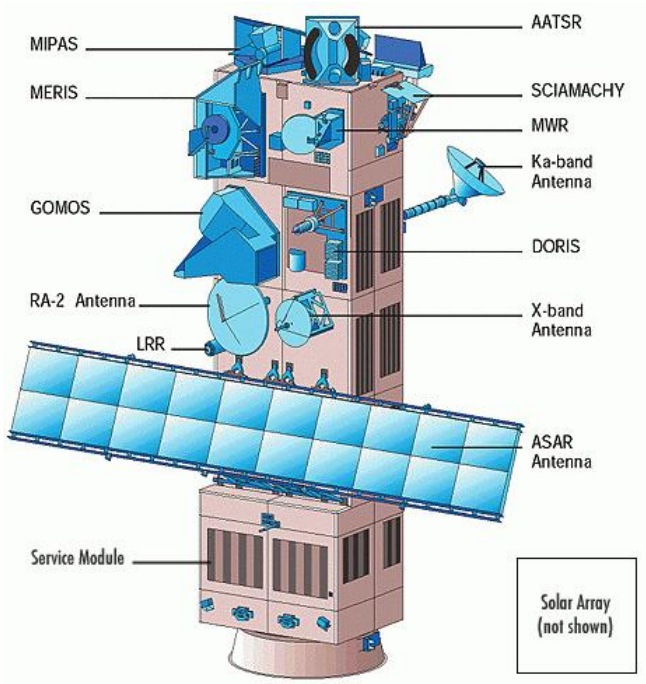
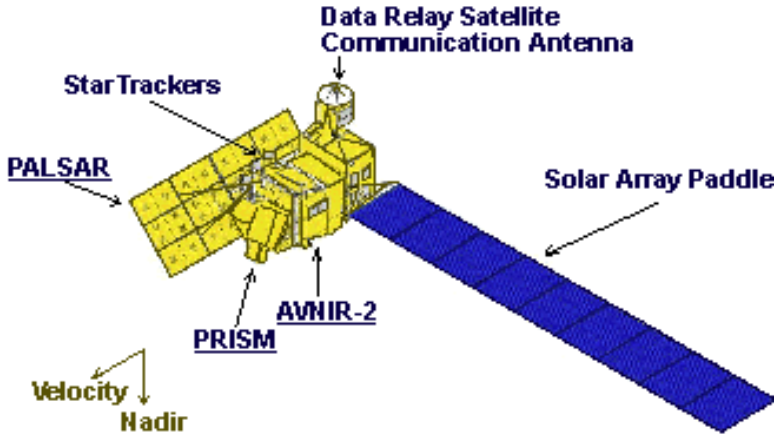
InSAR training 2024







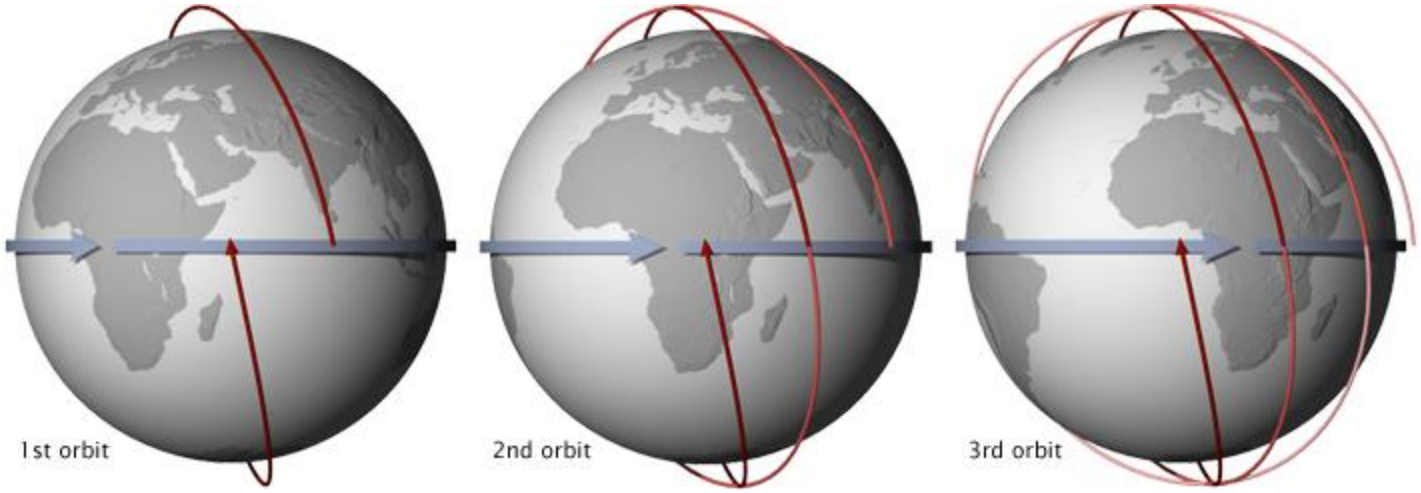
SAR missions

Considerations for SAR missions

When designing a SAR satellite mission, mission scientists and engineers typically consider the following first:

- Orbit style
- Radar band (wavelength)

Typical properties of SAR satellite orbits

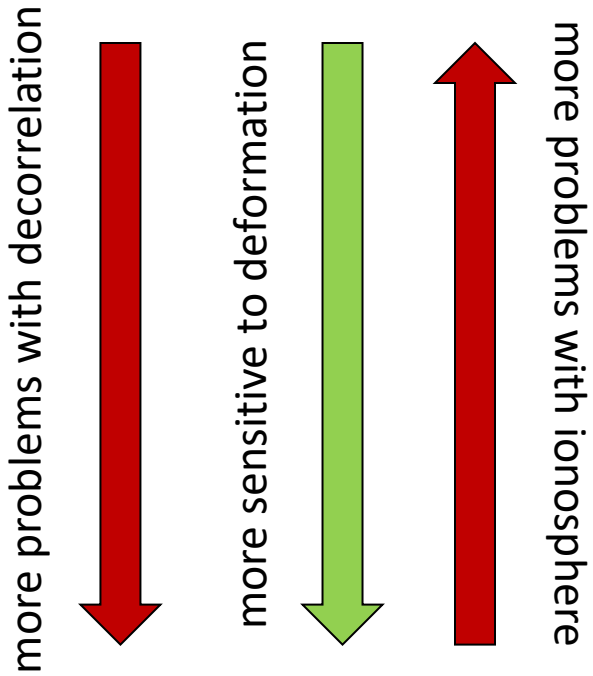


SAR satellites are typically in polar, sun-synchronous orbits

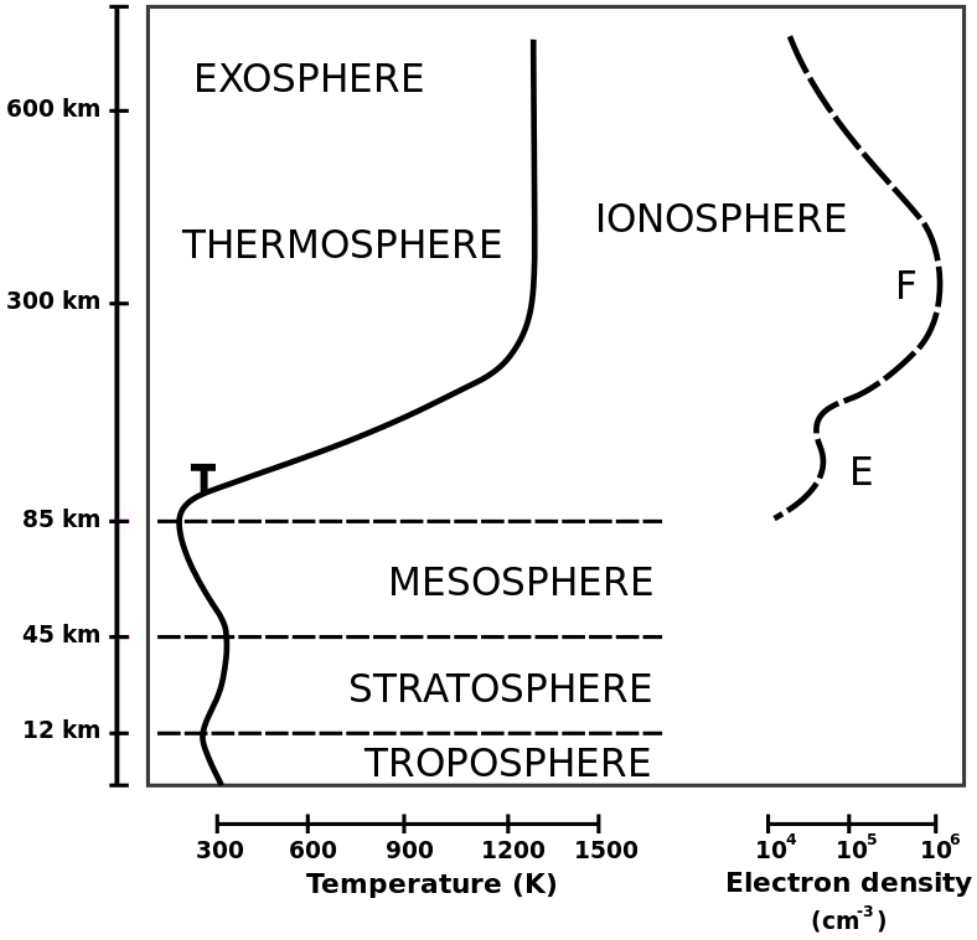
- Polar orbits => orbits that fly over both poles
- Sun-synchronous => fly over each point on the ground at the same local solar time on each pass
- Orbit timing can be chosen to maximize solar illumination (generate more power!)

Radar bands

Band	Frequency (GHz)	Wavelength (cm)	notes
P	0.3–1	100–30	Only on UAVSAR
L	1–2	30–15	
S	2–4	15–7.5	
C	4–8	7.5–3.75	
X	8–12.5	3.75–2.4	
Ku	12.5–18	2.4–1.7	Only on UAVSAR or ground-based SAR



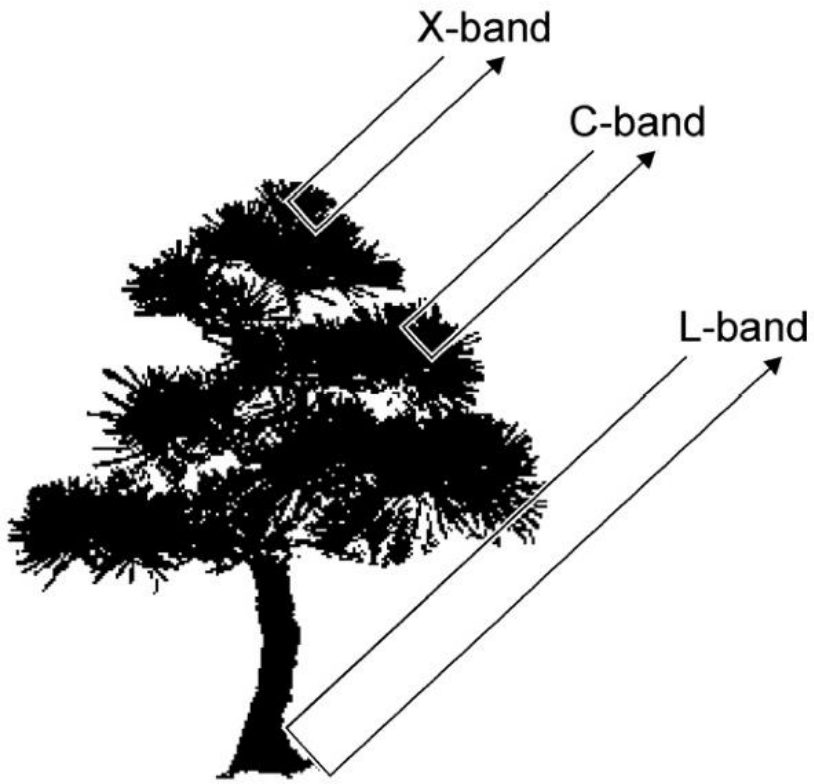
Ionosphere distortions in InSAR



The ionosphere, a layer of the upper atmosphere which is home to electrically charged particles, is a major consideration when selecting a radar band

- Microwave radiation is refracted through interactions with charged particles
- This effect is dispersive (frequency dependent) and affects lower frequencies (longer wavelengths) more strongly
- L-band radars are frequently affected; C-band radars are rarely affected; X-band typically not
- Periods of solar storms (with elevated total electron count) typically show stronger effects

Volume scattering of radar



Radar wavelength determines the penetration depth of the radar into vegetation

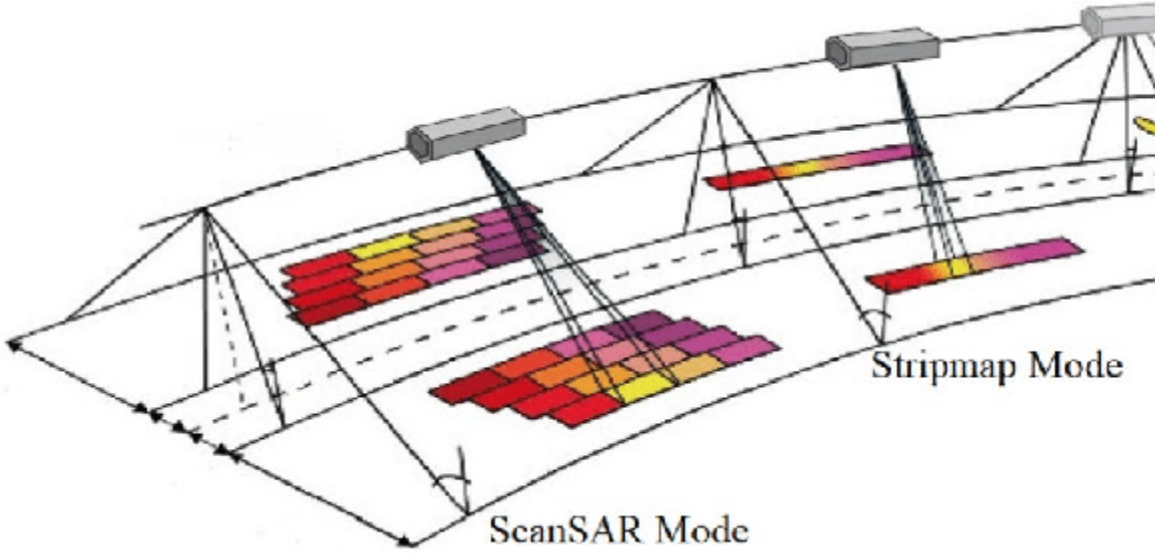
- X-band radar (TerraSAR-X, Cosmo-Skymed, ICEYE) scatters off of the canopies of trees
- C-band radar (Sentinel-1) scatters off of the branches of trees
- L-band radar (ALOS-2, NISAR) penetrates deeper into trees and scatters off of the trunks

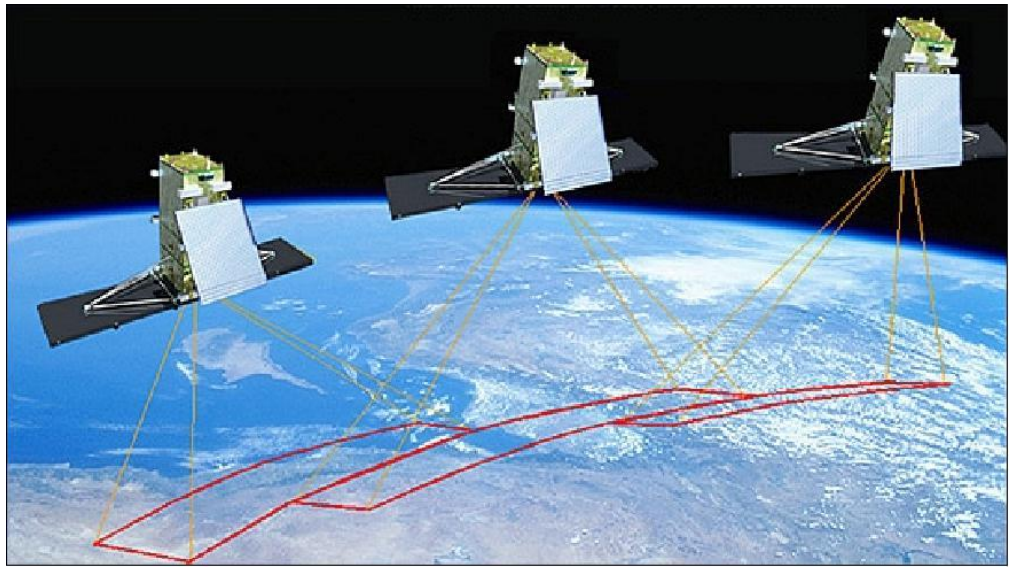
In general, longer wavelength radars are less affected by decorrelation from vegetation

Trends in SAR mission design

Recent SAR missions generally show improvements over previous offerings in the following ways:

- Increased swath coverage (image a larger area)
- Reduced revisit time (related to above)
- Constellations of multiple satellites (reduces revisit further)
- Increased duty cycle (more operating time per orbit, more images collected)





Current SAR satellite missions

Mission	Operator	Repeat (days)	Wavelength (cm)
Sentinel-1 (2014–) Currently 1 satellite, usually 2	ESA / Copernicus (EU)	12	5.55 (C-band)
ALOS-2 (2014–)	JAXA (Japan)	14	23.6 (L-band)
TerraSAR-X (2007–) TanDEM-X (2010–)	DLR (Germany)	11	3.1 (X-band)
Cosmo-Skymed (2007–) 6 satellites	ASI (Italy)	16	3.1 (X-band)
Radarsat Constellation Mission (2019–) 3 satellites	CSA (Canada)	12	5.55 (C-band)
Radarsat-2 (2007–)	MDA (Canada, commercial)	24	5.5 (C-band)

SENTINEL-1, Copernicus (EU; operated by European Space Agency)
1A 2014–, 1B 2016–2022, 1C 2024(?)

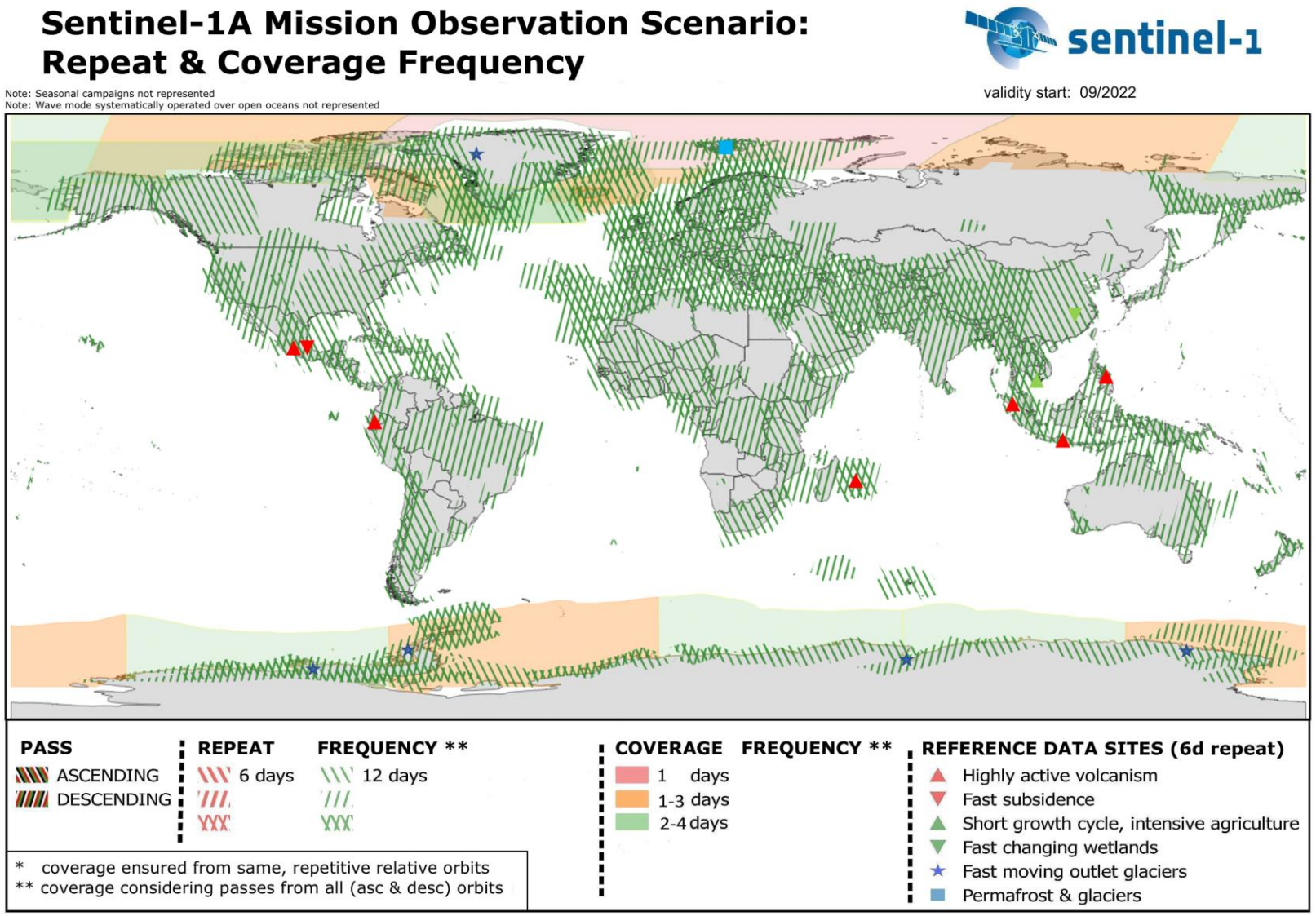
C-band, wavelength = 5.55 cm
12-day repeat coverage in CA,
6-day repeat coverage in Europe (with 2 satellites)

Common SAR satellites: Sentinel-1

Sentinel-1 has a fixed acquisition plan, with fixed beam modes and polarizations for each location

Most of the continental US is covered every 12 days in at least one acquisition geometry (ascending or descending)

Data access is free and open



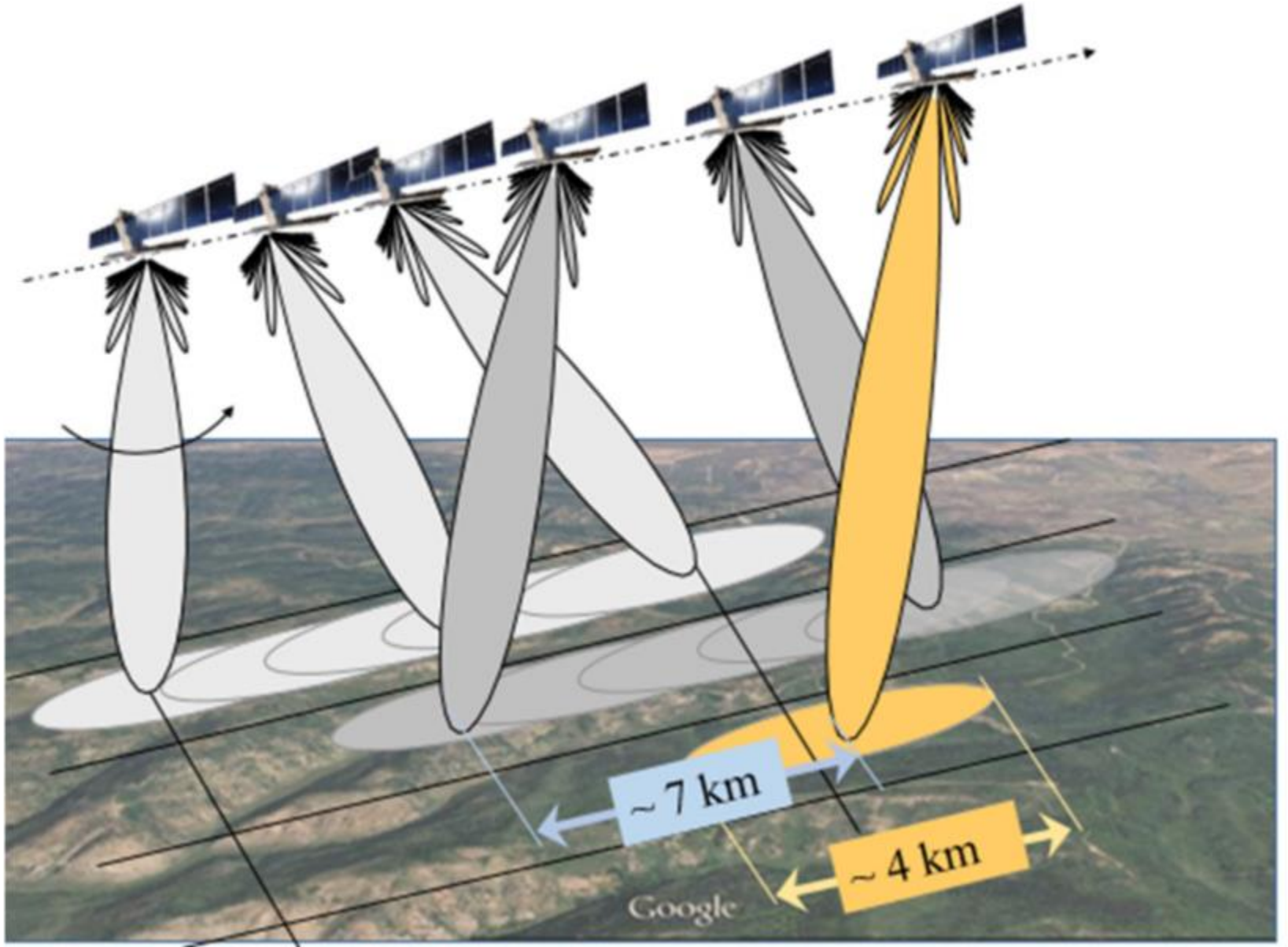
Common SAR satellites: Sentinel-1

Sentinel-1 interferometric wideswath (IW) mode is the standard mode over land

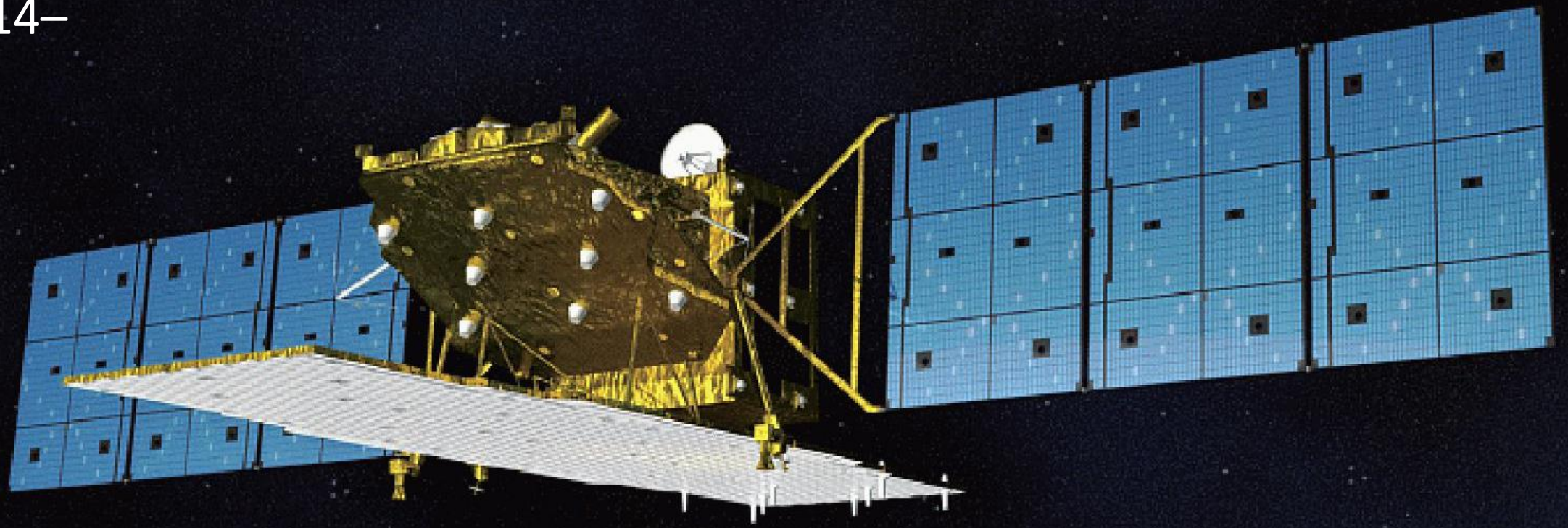
It has a 250 km wide swath, divided into three subswaths

Acquisitions are all right-looking

Images are acquired in TOPS (Terrain Observation by Progressive Scans) mode, in which the radar beam is steered backwards and forwards in a series of 'bursts'



ALOS-2, JAXA (Japan)
2014–



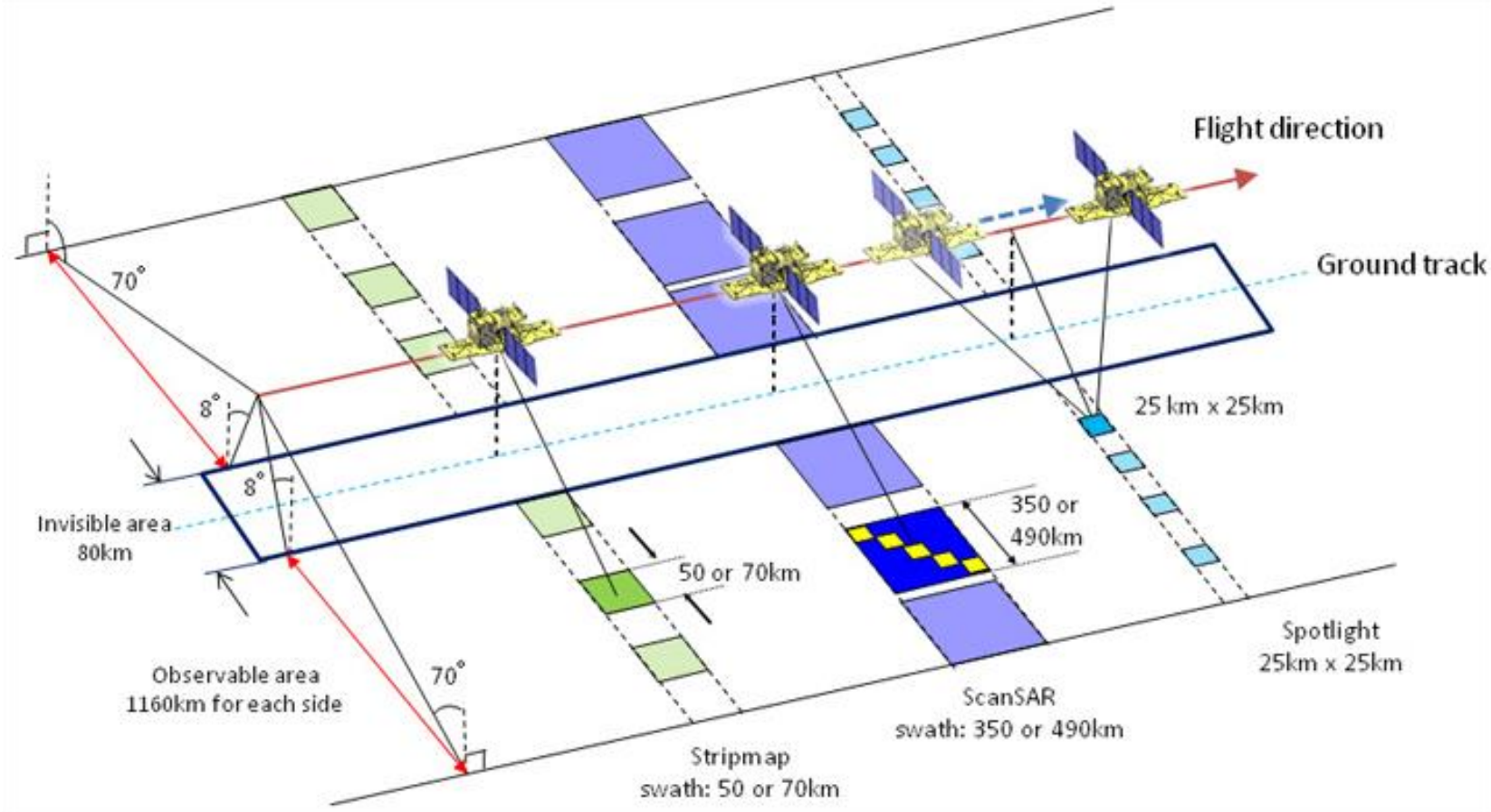
L-band, wavelength = 23.6 cm
14-day orbital repeat
Multiple beam modes

Common SAR satellites: ALOS-2

ALOS-2 has a wide variety of beam modes, and both right- and left-looking capability

The result is that there are many fewer repeat observations compared with Sentinel-1, although there is less decorrelation typically over time

Data access is limited



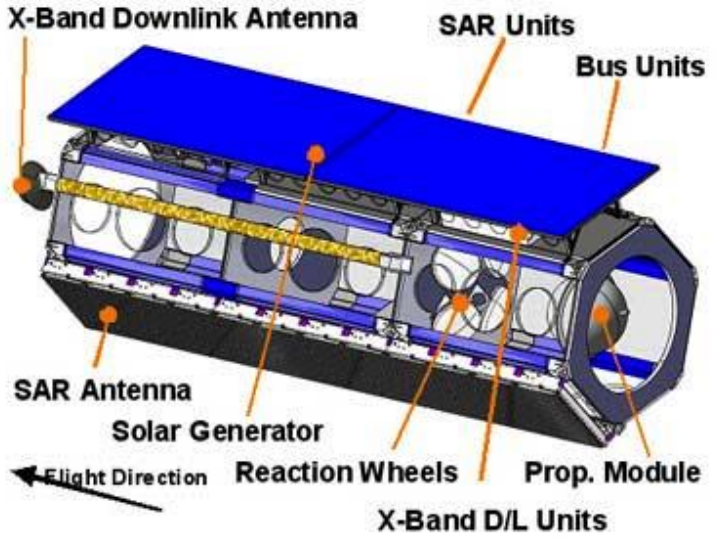
Common SAR satellites: TERRASAR-X

Mission duration: 2007–

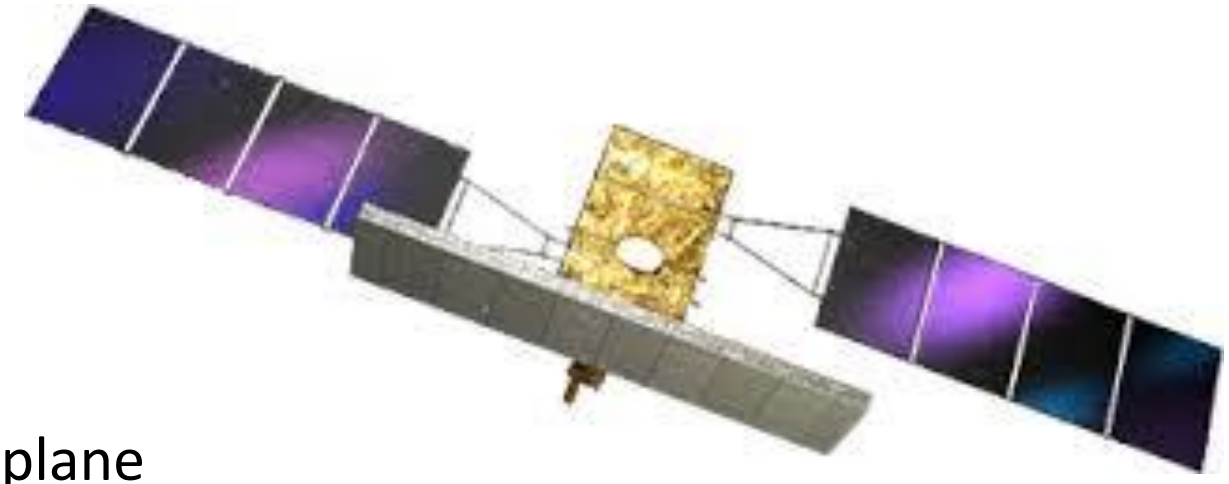
Orbit at 514 km, 11 day repeat

X-band radar, wavelength 3.1 cm, fine beam, strip-map and SCANSAR modes

Data not available for free for commercial use



Common SAR satellites: COSMO-SkyMed



Mission duration: 2007–

4 satellite constellation in same orbital plane

2 next generation satellites launched (of 4)

Orbit at 619 km, 16 day repeat

X-band radar, wavelength 3.2 cm, spotlight (fine-beam), stripmap and SCANSAR modes

Current SAR satellite missions (more obscure)

Mission	Operator	Repeat (days)	Wavelength (cm)
ICEYE (2018–) Over 30 satellites	ICEYE (Finland, commercial)	1–22	3.1 (X-band)
Capella (2020–) 4 satellites	CapellaSpace (US, commercial)	n/a	3.1 (X-band)
SAOCOM (2018–) 2 satellites	CONAE (Argentina)	16	23.5 (L-band)
PAZ (2018–) (TerraSAR-X clone)	Hisdesat (Spain, commercial)	11	3.1 (X-band)

Legacy SAR satellite missions

Mission	Operator	Repeat (days)	Wavelength (cm)
ERS (1991–2011)	ESA	35	5.63 (C-band)
Envisat (2002–2011)	ESA	35	5.62 (C-band)
Radarsat (1995–2013)	CSA (Canada)	24	5.6 (C-band)
JERS (1992–1998)	JAXA (Japan)	44	23.5 (L-band)
ALOS (2006–2011)	JAXA (Japan)	46	23.6 (L-band)

Legacy SAR satellites: ERS

ERS – ‘European Remote Sensing’

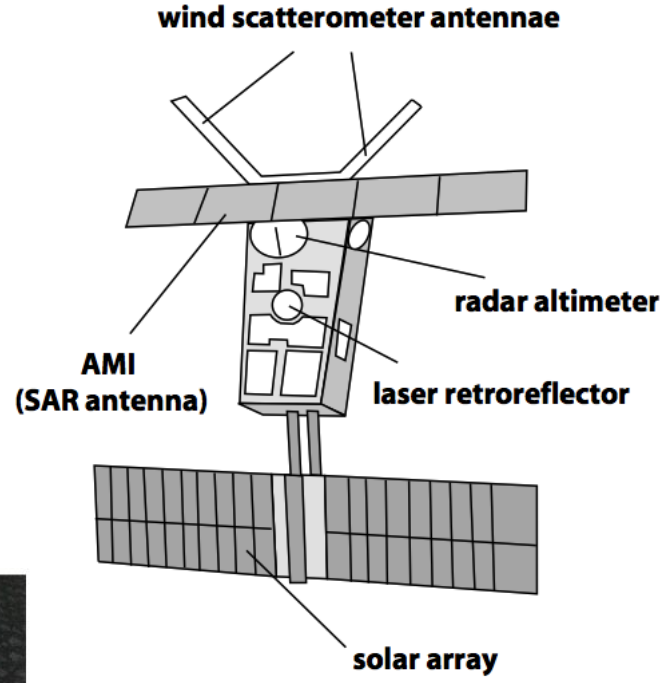
Mission duration: ERS-1: 1991–2000, ERS-2: 1995–2011 (tandem mission 1995–1996 and 1999–2000; reduced capability 2001–)

Orbit at 780 km, 35 day repeat, sun-synchronous

C-band radar, wavelength 5.67 cm, incidence 23°

No onboard data storage

Data freely available from ESA



Legacy SAR satellites: Envisat

Envisat: ‘Environment satellite’

Mission duration: 2002–2011

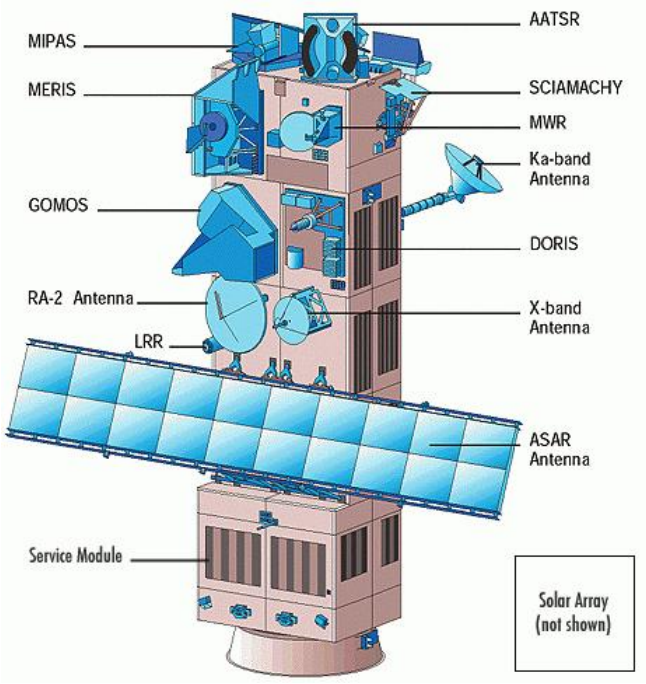
Orbit at 780 km, 35 day repeat (30 day after 2010), sun-synchronous (ERS-2 and Envisat orbit 28 minutes apart)

C-band radar, wavelength 5.62 cm, incidence 19–44° (7 beam modes, plus SCANSAR)

Onboard data storage and data relay capability

9 other instruments (including MERIS)

Data freely available from ESA



Legacy SAR satellites: ALOS

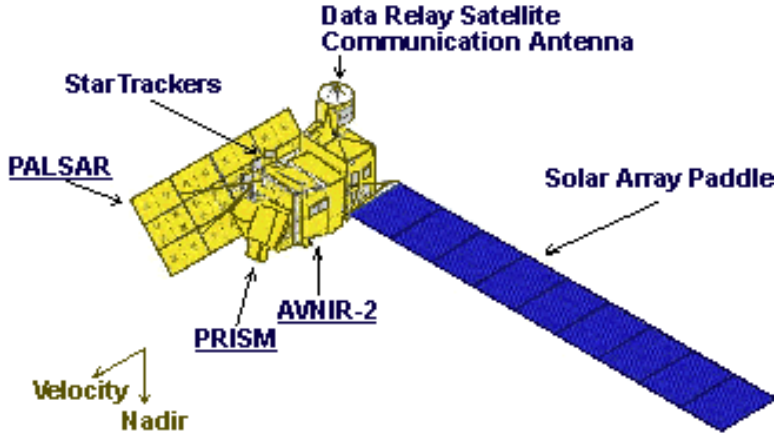
ALOS: ‘Advanced Land Observation Satellite’

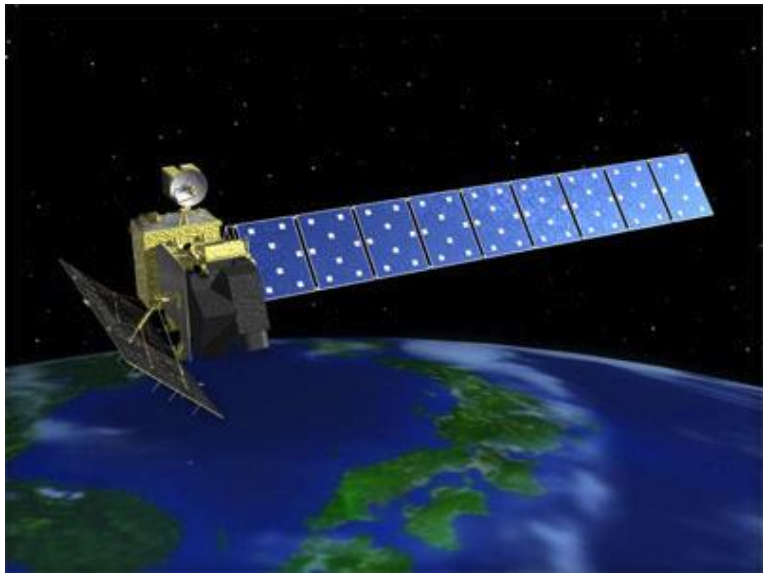
Mission duration: 2006–2011

Orbit at 690 km, 46 day repeat, sun-synchronous

L-band radar, wavelength 23.5 cm, incidence 8–60º (5 beam modes, plus SCANSAR)

Some data available through ASF





Not a SAR satellite: UAVSAR

Gulfstream jet with modular SAR loadout

Operated by NASA since 2007

Most common imaging radar used is L-band (also Ka-band and P-band options)

Flown in campaigns over targets in North America by request

Biggest advantage is ability to choose your own flight lines to optimize observations

The future!

NISAR (NASA/ISRO)
Launch expected July 2024

L-band, wavelength = 23.6 cm
12-day repeat coverage globally, ascending and descending
Left-looking