GEOS 639 – INSAR AND ITS APPLICATIONS

GEODETIC IMAGING AND ITS APPLICATIONS IN THE GEOSCIENCES

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Lecture 2: Introduction to Geodetic Imaging I – What is Geodesy; Datums & Projections; Sensor Types

ASF

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THE PROBLEM OF GEODESY

What is Geodesy

- Classical definition by F. R. Helmert (1880): **Geodesy is the "science of the measurement and mapping of the earth's surface."** It includes **determination of earth's shape** (**Geometric Geodesy**), and gravity field (**Physical Geodesy**), as well as **temporal variations** of these variables.

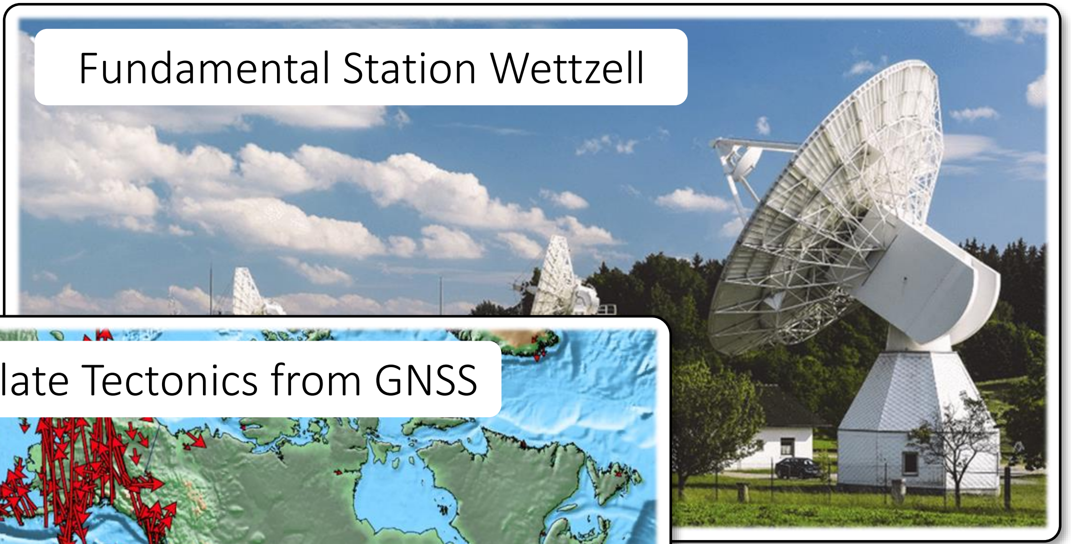
The Problem of Geodesy

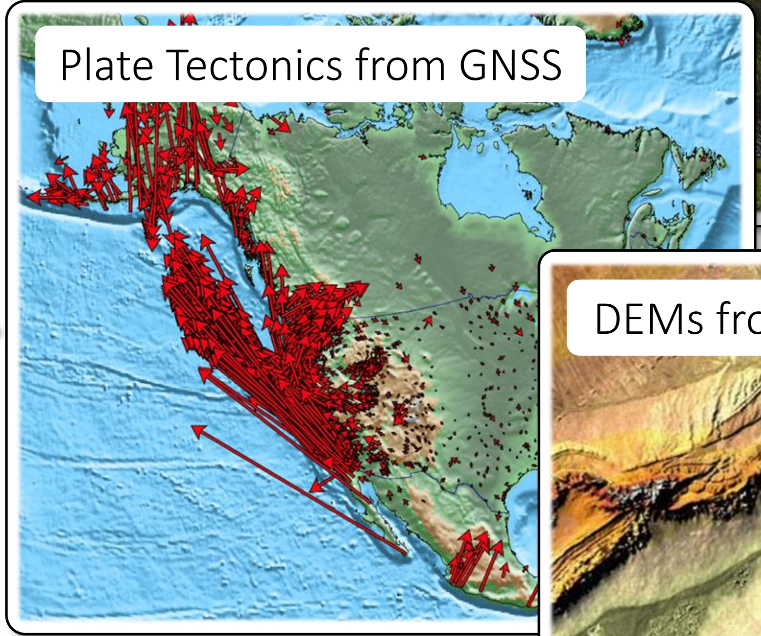
“The problem of geodesy is to determine the figure of the earth [and of other celestial bodies] as functions of time.“ [Fischer, 1975]

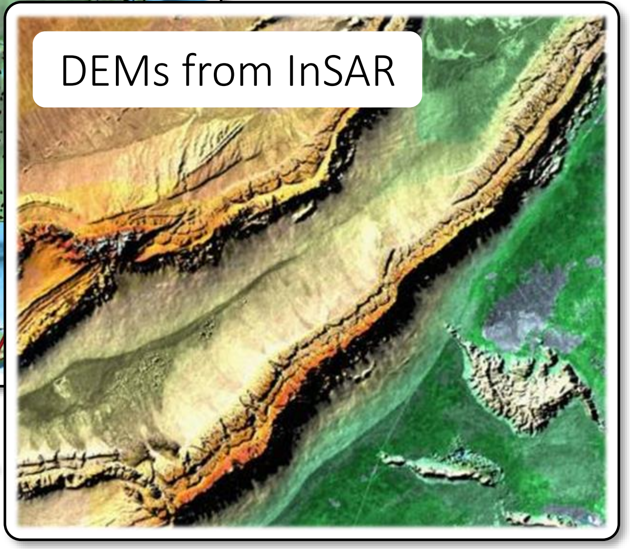
- **Determining the figure of the earth includes measuring its *physical* and *mathematical* surface**
  - Physical surface of the earth is the border between solid earth and atmosphere → Geometric Geodesy is concerned with establishing coordinate systems and assigning coordinates to locations on the physical surface
  - Physical geodesy is concerned with determining the Earth’s gravity field, which is necessary for establishing heights. It establishes the Geoid (surface of constant gravity potential) as the earth’s mathematical surface.

Applications of Geodesy

- Typical applications of Geodesy include:
  - Satellite orbit determination
  - Position the earth in a reference system based on quasars
  - Use spaceborne sensors to study variations in mean sea level, ocean circulation, ground water & ice sheet changes
  - Measure earths gravity field and its temporal changes
  - Use Global Navigation Satellite Systems (GNSS) to study plate tectonics, volcanic activity, post-glacial rebound, …
  - Use remote sensing to map the earth's topography & motion
  - Geodesy plays an active role in disciplines of land surveying, photogrammetry, remote sensing, hydrography, cartography, geographic information science, and geospatial computing.





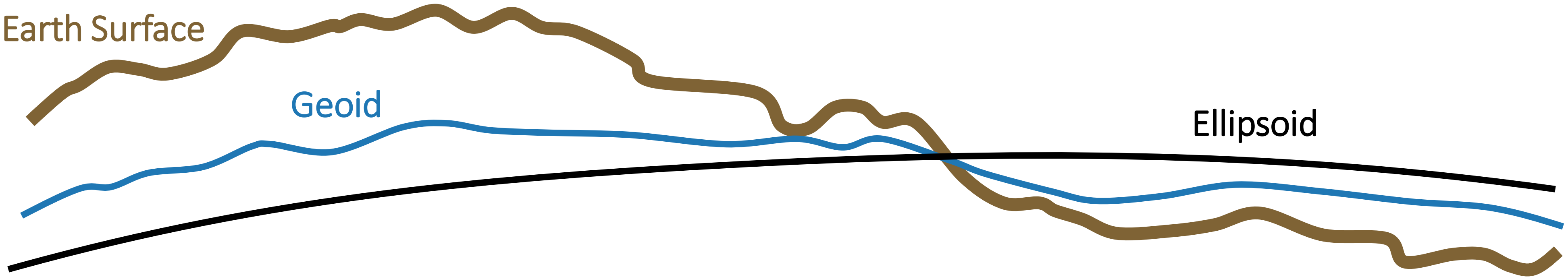


GEODETIC REFERENCE SYSTEMS

Geodetic Reference Systems

- **Reference systems are needed to describe the motion of the earth in space (celestial system), and quantify earth's surface geometry (shape) and its change (terrestrial system)**
- For global applications, the use of three-dimensional Cartesian coordinates in Euclidian space is adequate

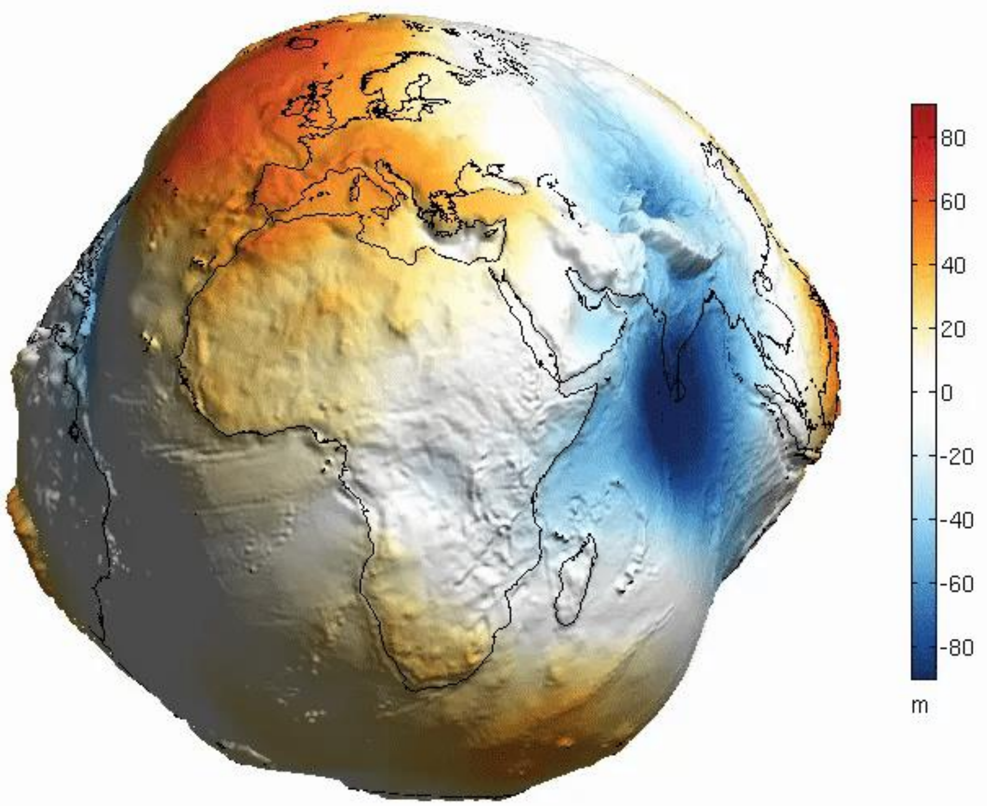
- Large variations in surface topography make it impossible to approximate the shape of the Earth with simple mathematical models → two main reference surfaces were established to approximate the shape of Earth
  - One reference surface is called the ***Geoid***,
  - the other reference surface is the ***Ellipsoid***



Earth Surface and Reference Surfaces

The Geoid and the Vertical Datum

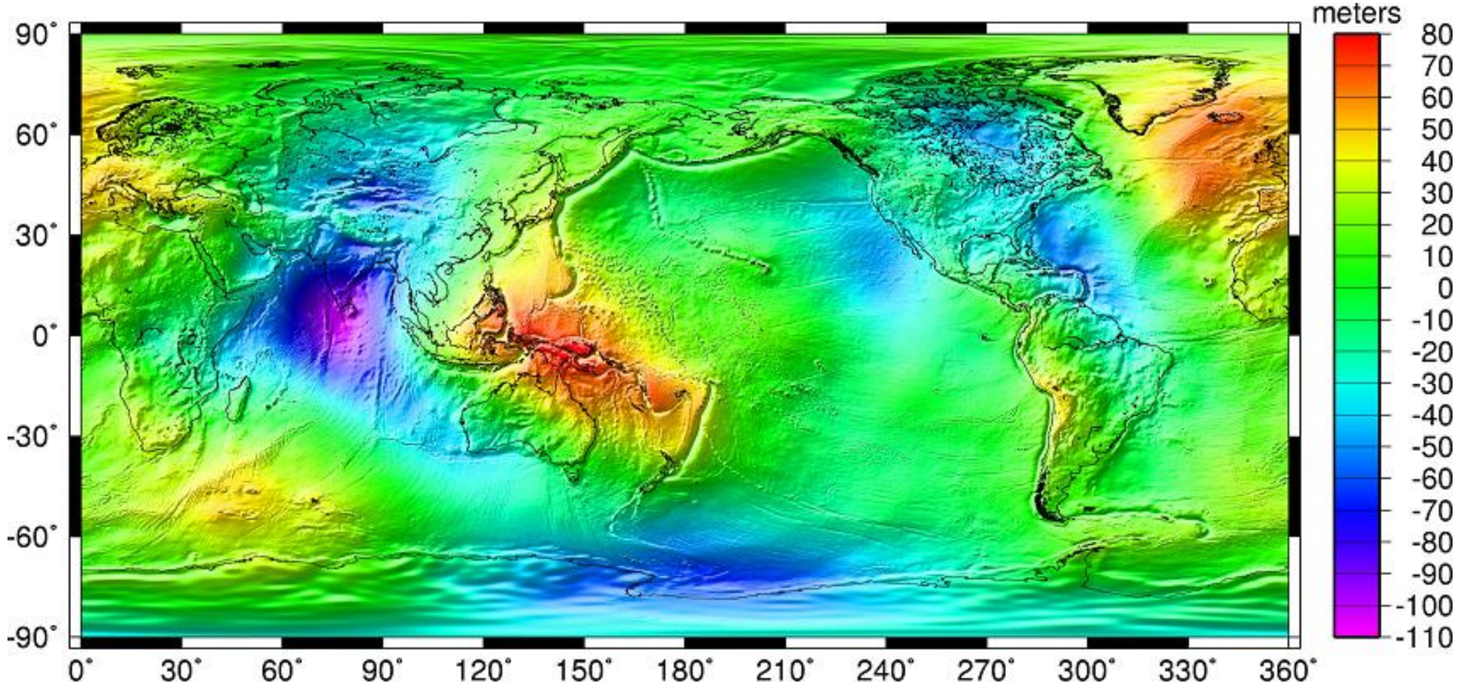
- We can simplify matters by imagining that the entire Earth’s surface is covered by water.
- If we ignore tidal and current effects on this ‘global ocean’, the resultant water surface is affected only by gravity.
- This has an effect on the shape of this surface because the direction of gravity - more commonly known as plumb line - is dependent on the mass distribution inside the Earth.
- Due to irregularities or mass anomalies in this distribution the 'global ocean' results in an undulated surface.
- **This surface is called the *Geoid*.**



Geoid height (EGM2008, nmax=500)

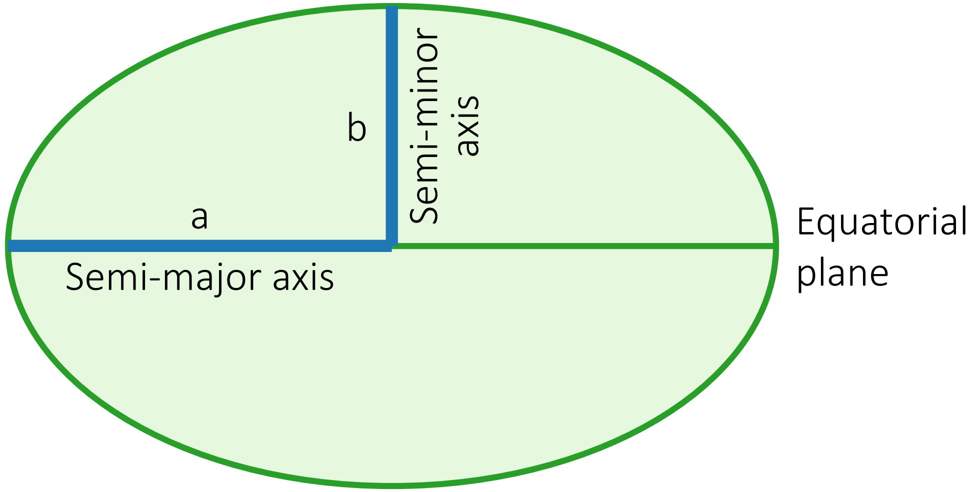
The Geoid and the Vertical Datum

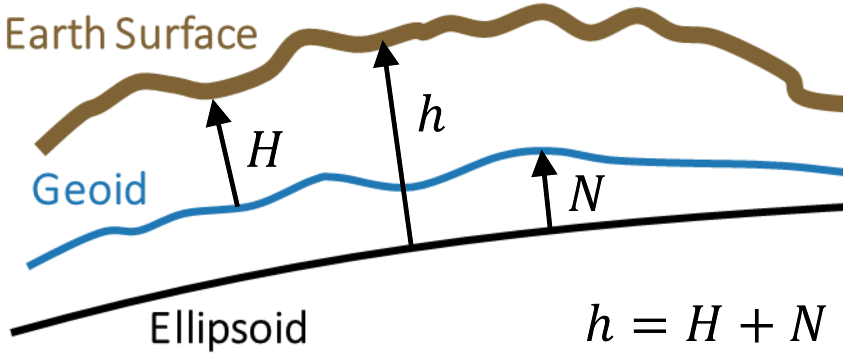
- Where a mass deficiency exists, the Geoid will dip below the mean ellipsoid and vice versa
- These influences cause the Geoid to deviate from a mean ellipsoidal shape by up to +/- 100 meters.
- The biggest undulations are: minimum in the Indian Ocean (N = -100 meters) and maximum in the northern part of the Atlantic Ocean with N = +70 meters (figure below).
- Heights measured relative to the Geoid are called **orthometric heights**



The Ellipsoid

- We also need a reference surface for the description of the horizontal coordinates (i.e. geographic coordinates) of points of interest.
- The most convenient geometric reference is the ***oblate ellipsoid*** (left figure). It Is chosen to fit the Geoid to a first order approximation.
- Heights measured relative to the Ellipsoid are called **ellipsoid heights**
- Ellipsoid h, orthometric H, and geoid heights N are related via: $h = H + N$



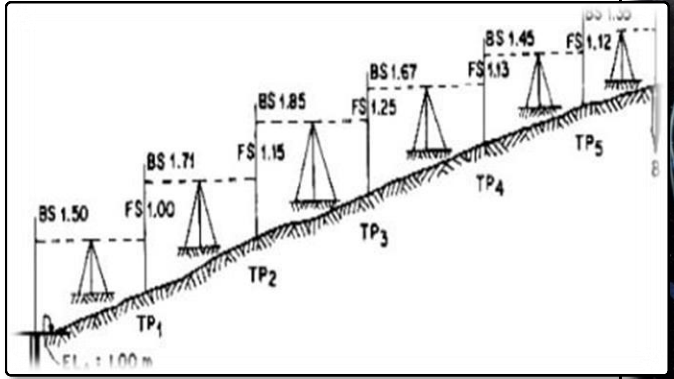


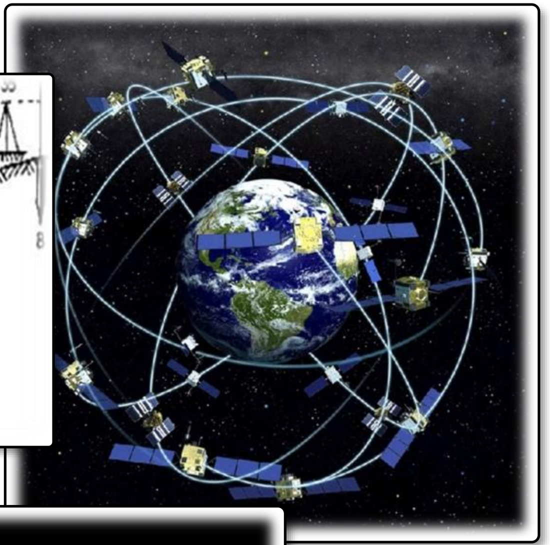
Relationship between ellipsoid, orthometric, and geoid heights

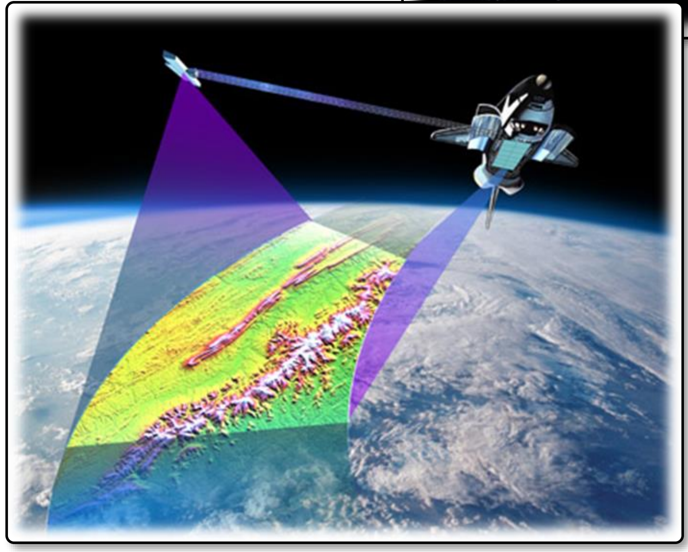
Think – Pair – Share

Orthometric vs Geometric Heights

- **You may wonder why you should care about orthometric vs geometric heights. Turns out different measurement systems give you different height information:**
  - **Q1**: Which of these techniques/data may provide orthometric and which geometric heights? [Levelling | GPS | SRTM DEM | InSAR]
  - **Q2**: Different countries have defined a wide range of different reference ellipsoids. Why may that be?







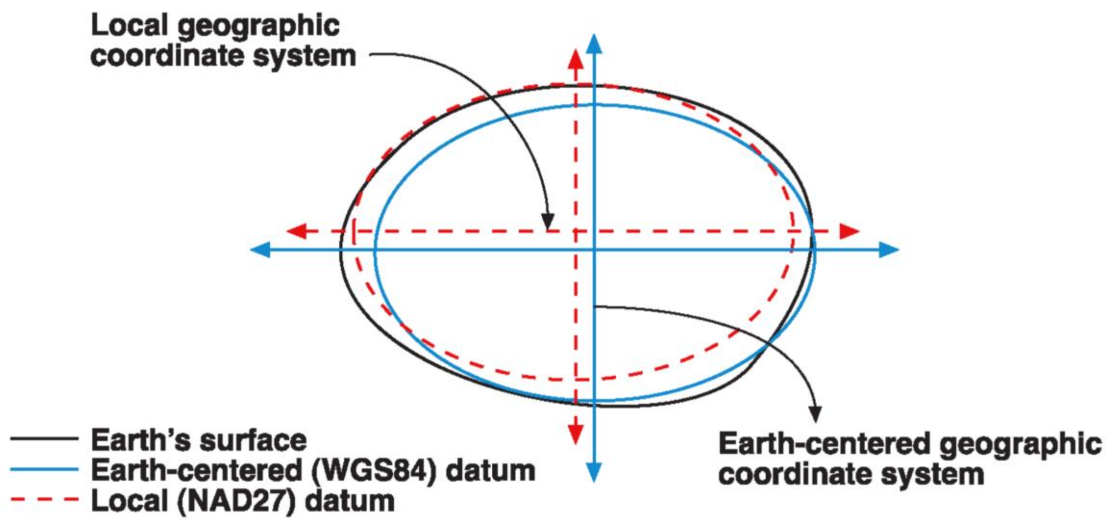
Local Ellipsoids and Local Datums

- ***Local ellipsoids*** were established to fit the Geoid over an area of local interest
- In contrast, ***global reference ellipsoids*** approximate the Geoid as a mean Earth ellipsoid.
- Popular global ellipsoids include WGS-72 (World Geodetic System 1972 established by the National Geospatial Intelligence Agency in 1972), GRS-80 (Geodetic Reference System 1980; originally used by WGS-84; now WGS-84 differs from GRS-80), and WGS-84 established by NGA as reference coordinate system for the Global Positioning System (GPS)
- A local datum aligns its spheroid to closely fit the earth's surface in a particular area

Datum	Ellipsoid	Datum shift (m)* (Dx,	Dy,	Dz)
Alaska (NAD-27)	Clarke 1866	-5	135	172
Bahamas (NAD-27)	Clarke 1866	-4	154	178
Bermuda 1957	Clarke 1866	-73	213	296
Central America (NAD-27)	Clarke 1866	0	125	194
Bellevue (IGN)	Hayford	-127	-769	472
Campolnchauspe	Hayford	-148	136	90
Hong Kong 1963	Hayford	-156	-271	-189
Iran	Hayford	-117	-132	-164

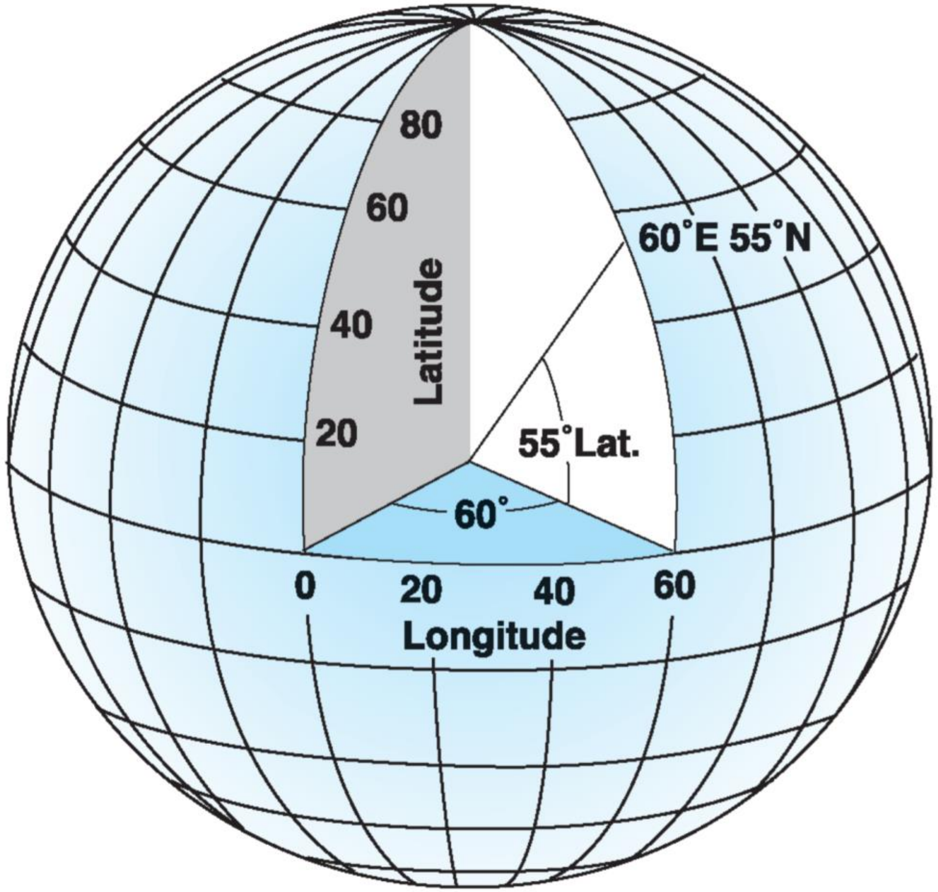
* positions compared to WGS84

Example local datums



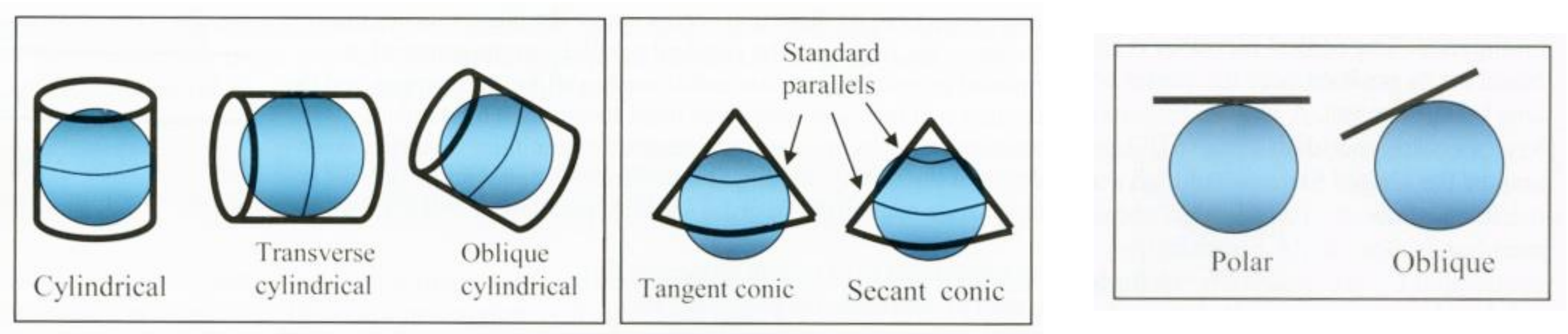
Geographic Coordinate Systems

- A geographic coordinate system (GCS) uses a 3-dimensional spherical surface to define locations on the earth.
- A GCS includes an angular unit of measure, a prime meridian, and a datum (based on a spheroid).
- A point is referenced by its longitude and latitude values. Longitude and latitude are angles measured from the earth's center to a point on the earth's surface.
- Latitude and longitude values are traditionally measured either in decimal degrees or in degrees, minutes, and seconds (DMS).
- Latitudes are measured relative to the equator and range from -90° (South Pole) to +90° (North Pole).
- Longitudes are relative to the prime meridian ranging from -180° when traveling west to 180° when traveling east.



Projection Coordinate Systems

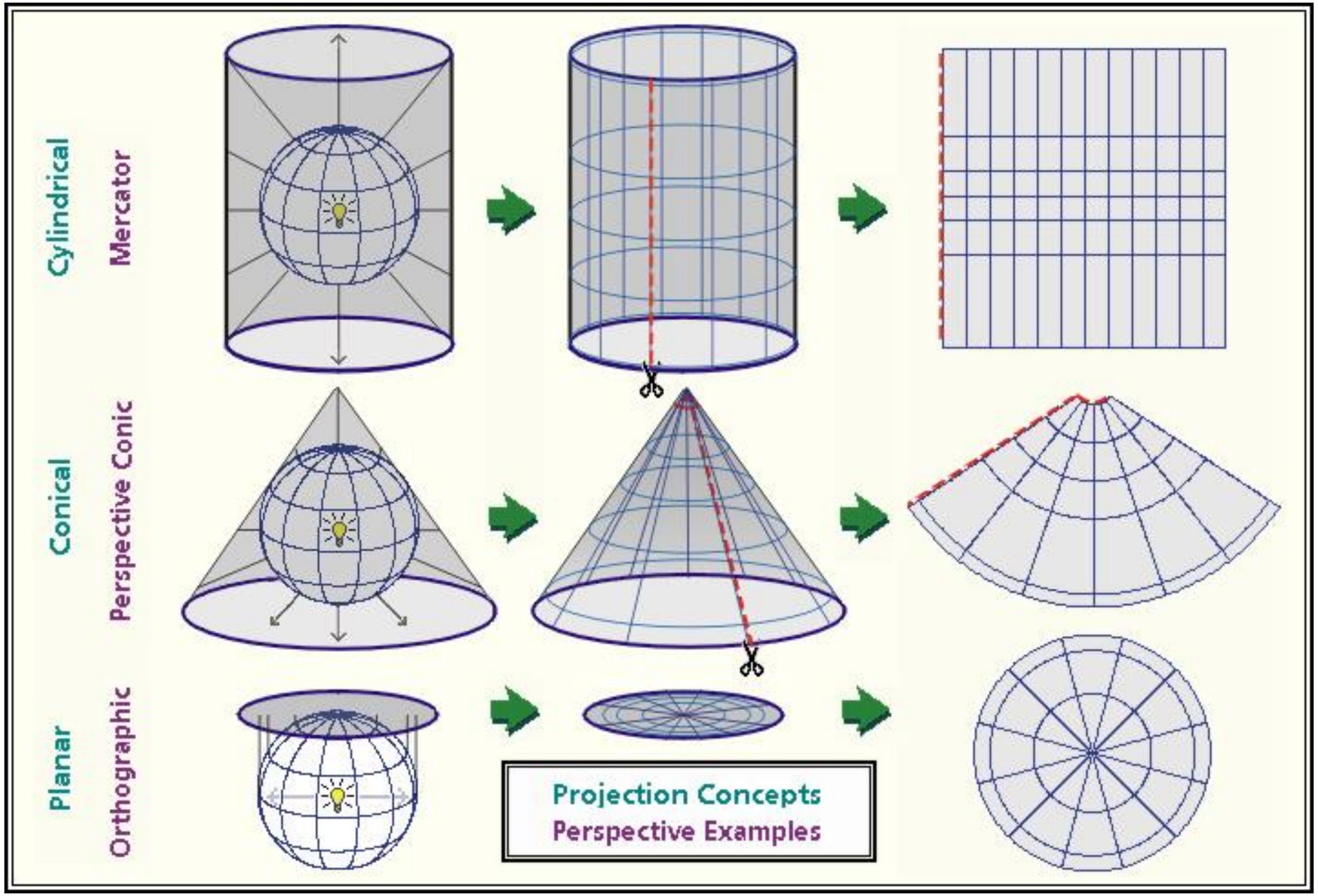
- Projected coordinate systems are defined on a flat, two-dimensional surface.
- Unlike a geographic coordinate system, a projected coordinate system has constant lengths, angles, and areas across the two dimensions.
- In a projected coordinate system, locations are identified by x,y coordinates on a grid, with the origin at the center of the grid.



Map Projection Types

Map Projections

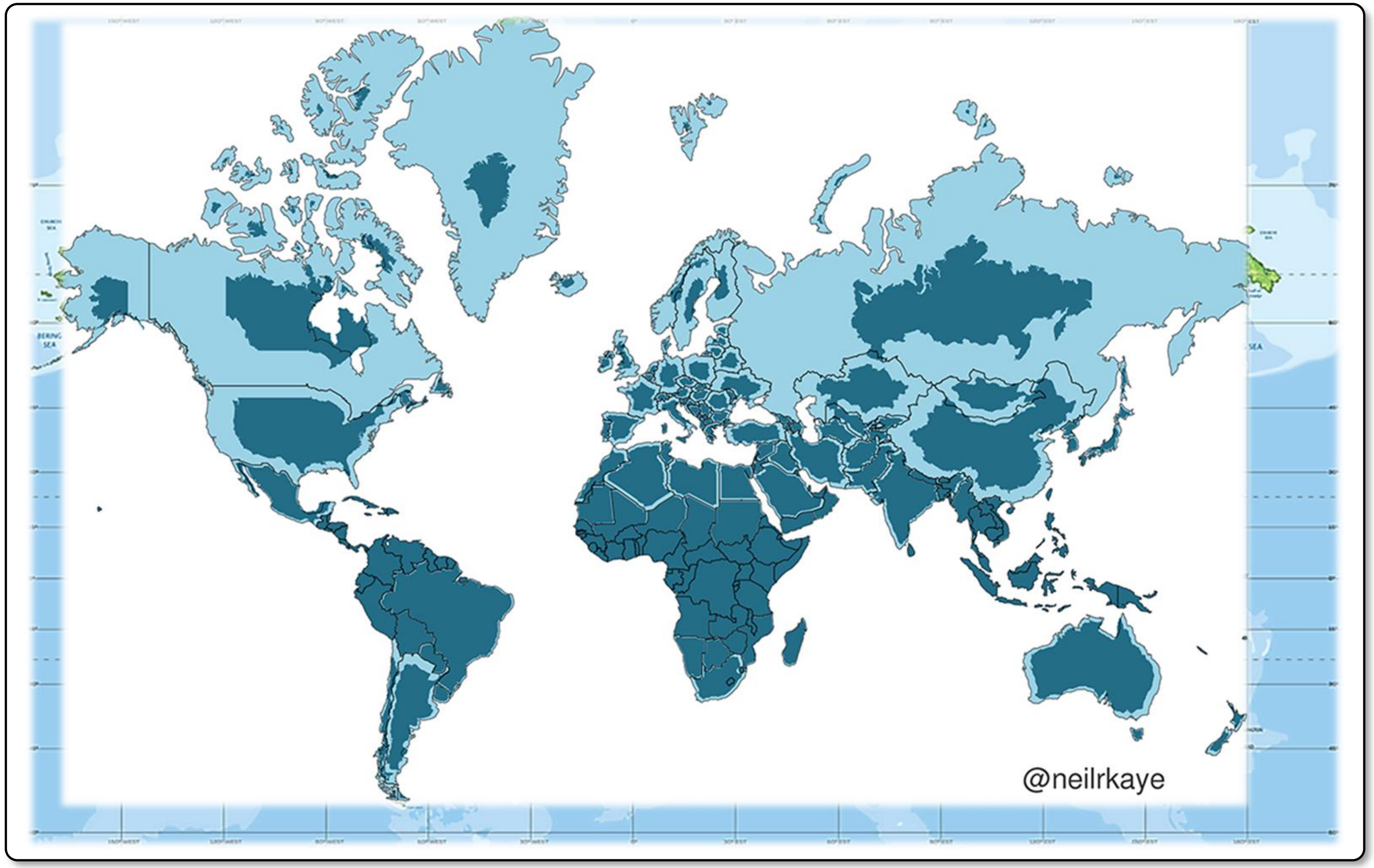
- The mathematical transformation of the 3-D surface into a flat map sheet is called map projection
- The visualizations on the right show how projections alter spatial properties leading to distortions.
  - **Conformal projections** preserve local shape (maintains all angles)
  - **Equal area projections** preserve the area of displayed features
  - **Equidistant maps** preserve the distances between certain points



Short Quiz

- What is the size ratio of Greenland and Africa?

Africa is almost 14 times larger than Greenland in area (30,200,000 km² compared to 2,166,086 km²)



Sensor Types Relevant for this Course

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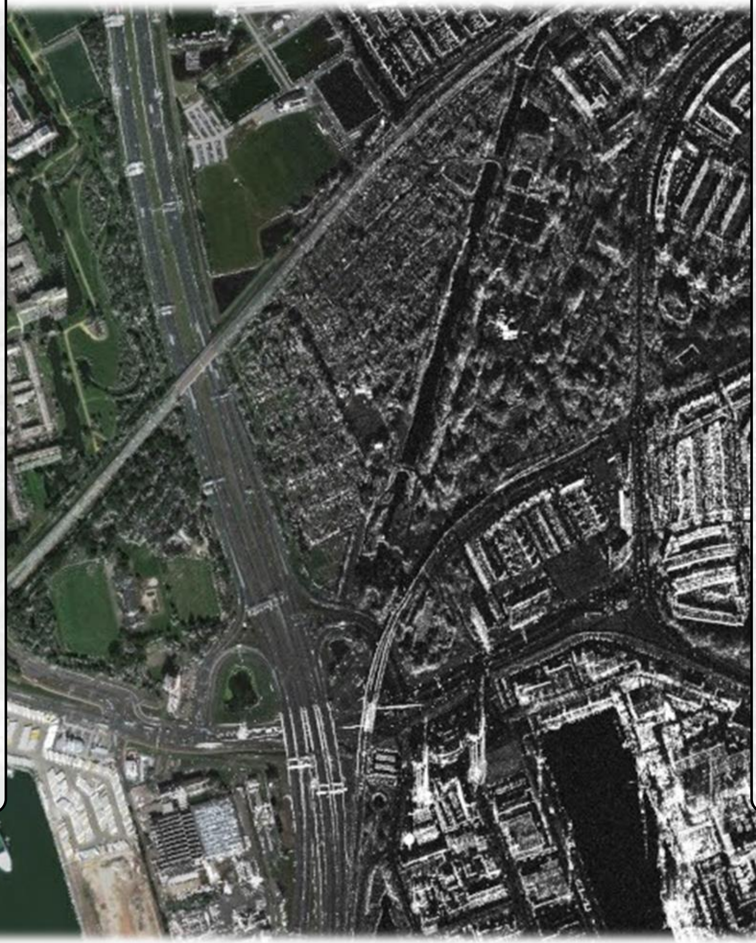
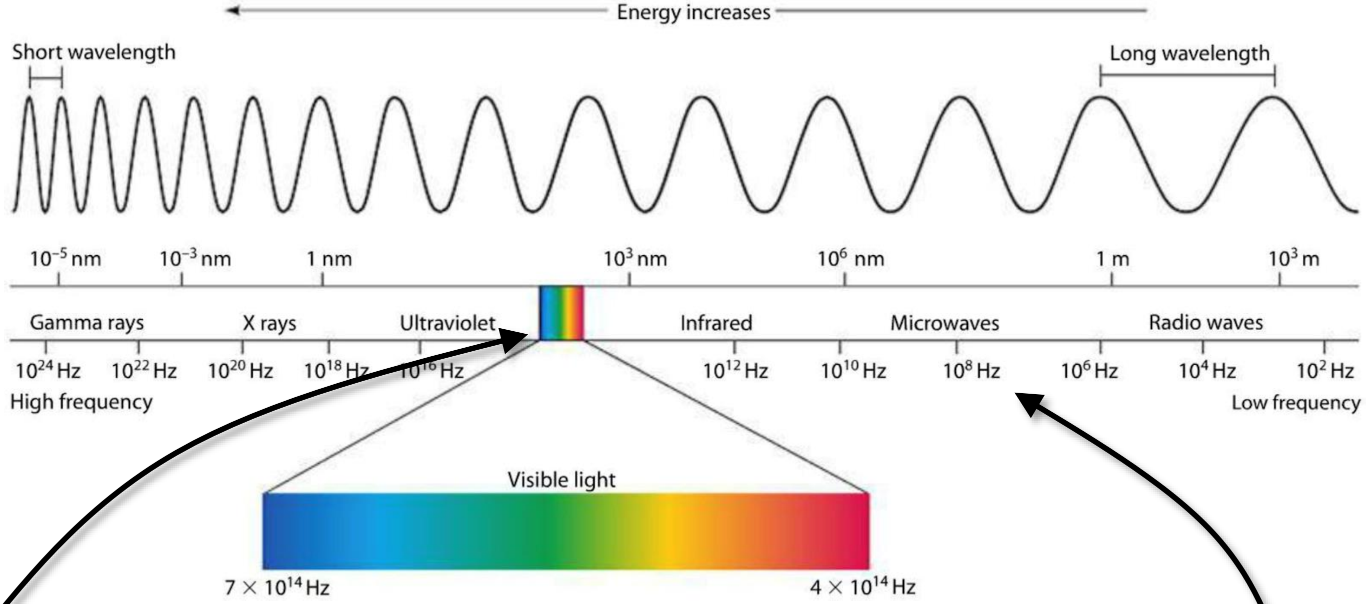
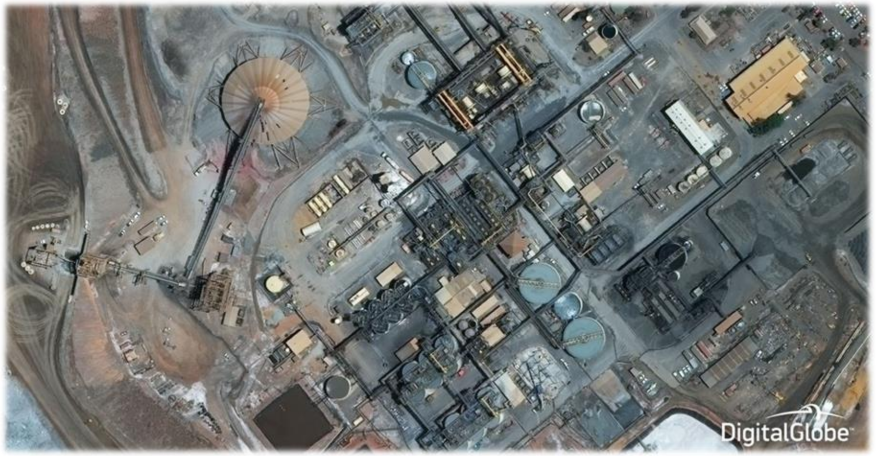
- **Electro Optical sensors**
  - Measuring surface reluctance
  - Illumination provided by the sun
  - Resolution: sub-meter and tens of meters
  - Repeat cycle daily to tens of days
- **Example sensors**:
  - Landsat Series
  - Worldview
  - Planet constellation



- **Synthetic Aperture Radar (SAR)**
  - Measuring radar backscatter
  - Illumination provided by sensor
  - Resolution: sub-meter to tens of meters
  - Repeat cycle days to tens of days
- **Example Sensors**:
  - Sentinel-1
  - NISAR (upcoming)
  - TerraSAR-X
  - Cosmo SkyMed
  - ALOS PALSAR and PALSAR-2

Sensors Mostly Used or Geodesy





Visual-range imagery

RGB-type

Synthetic Aperture Radar (SAR)

Single-scene and InSAR

Reading Assignment

- Next Lecture: Intro. To Geodetic Imaging – Optical Sensors

- To prepare for coming lectures, start reading:

SAR Handbook Chapter 2: SAR Principles, Data Access, and Basis Processing Techniques [Meyer, 2019]

Chapters 2.1 and 2.2

QUESTIONS?