GEOG 413/613

LECTURE 1

1

GEOG 413/613 Advanced GIS

Fall 2022

Lectures:
Tue: 10.00 - 11.20
Thu: 10.00 - 11.20

Labs:
Room 8-125
Mon: 15.00 – 17.50

Outline and notes:
https://gis.unbc.ca

2

High Accuracy Data Collection

- Geospatial data are collected by a variety of methods
  - Satellite remote sensing
  - Aerial remote sensing
  - Land surveying
  - Global navigation satellite system (GNSS)
    - Global Positioning System (GPS) is one type of GNSS

3

What is a GNSS?

- It is a satellite-based system that provides positioning, navigation, and timing services across the globe
- It provides location information about virtually any place on earth

4

4

Multiple GNSS exist

- The US NAVSTAR GPS
  - Navigational System with Time and Ranging (NAVSTAR)
  - Originally for the US Military but has been available to for civilian use
- The Russian GLONASS
  - Global Navigation Satellite System
- The EU's Galileo
- The China's COMPASS (BeiDou)

5

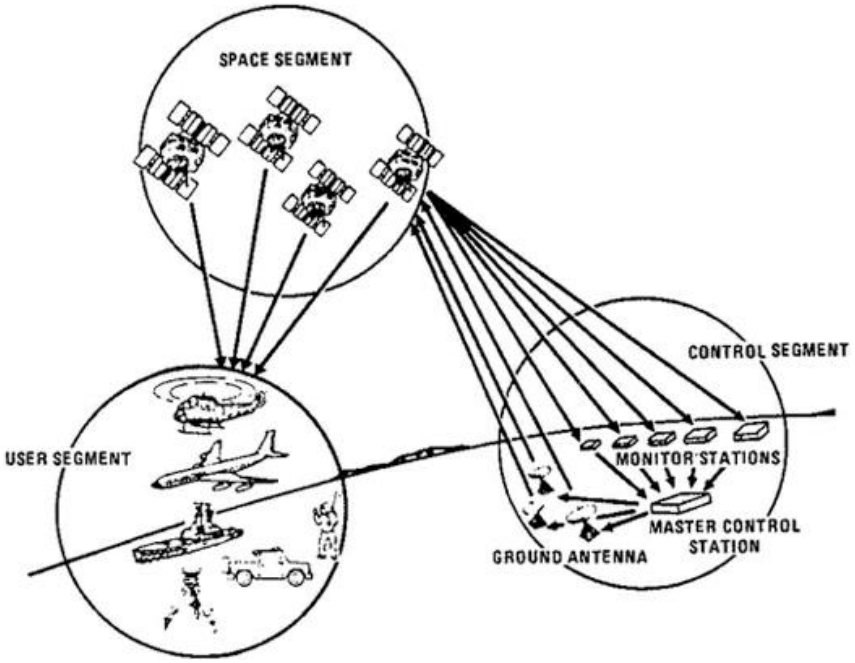
5

Segments of a GNSS

- 3 Segments
  - Space segment - the satellite constellation
  - Control segment - ground stations
  - User segment – receivers/antennas

6

6



Madry, Scott. Global Navigation Satellite Systems and Their Applications, Springer, New York.

7

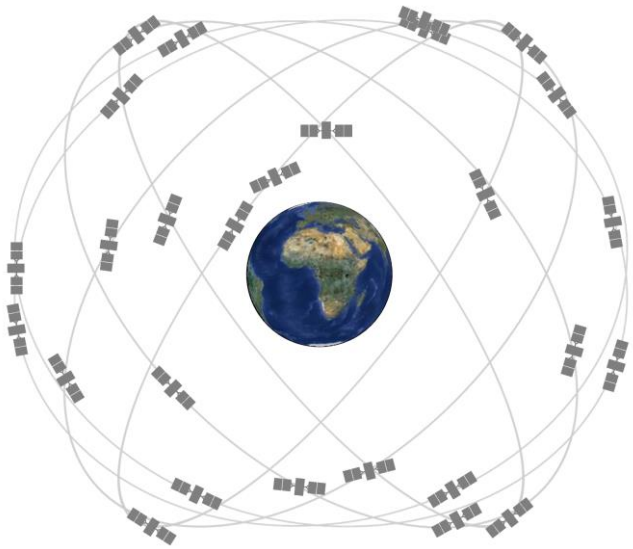
The Global Positioning System

- Space Segment
  - A constellation of 24 satellite slots at an altitude of about 20,200km
  - Satellites are positioned in 6 earth centered orbital planes.
  - The orbits are equally spaced (60^0) with an inclination of 55^0 relative to the equatorial plane
  - Designed to allow a minimum of 4 satellites at an unobstructed location at any given time
  - 24-hour, all weather, global user navigation and time determination capability

8

Space Segment

- The nominal orbital period is 11 h 59 min
  - every satellite orbits the globe 2 times a day



9

9

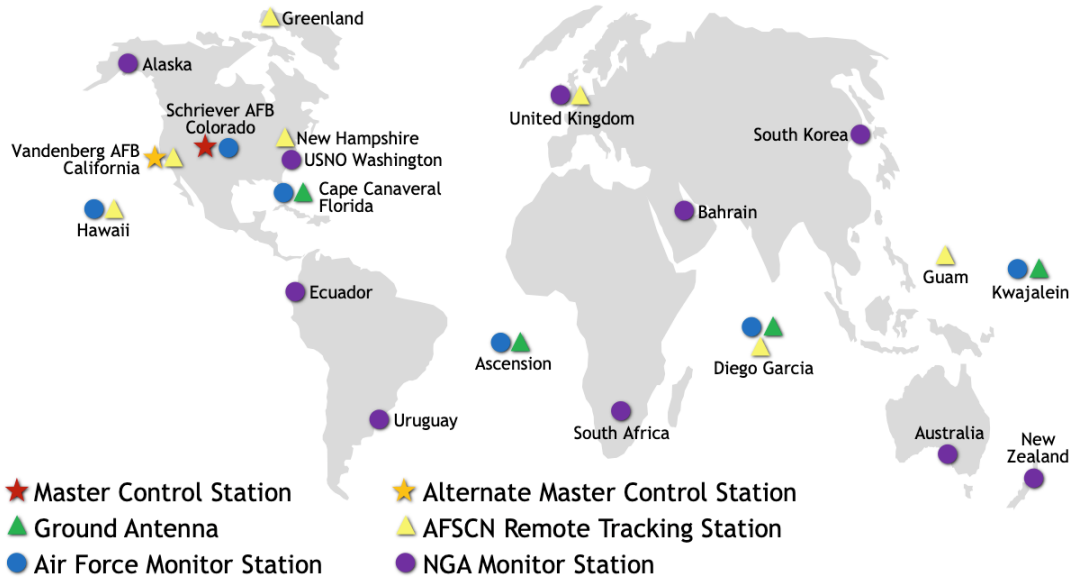
The Global Positioning System

- Control Segment
  - A network of ground facilities that track the GPS satellites
    - monitor transmissions, perform analyses, relay commands and data back to to the constellation.
      - a master control station transmits back to the satellites
      - some ground stations perform command and control
      - others perform monitoring service

10

10

GPS Control Segment



11

The Global Positioning System

- The User Segment
  - Handheld recreation units
  - Resource grade units
  - Survey grade units

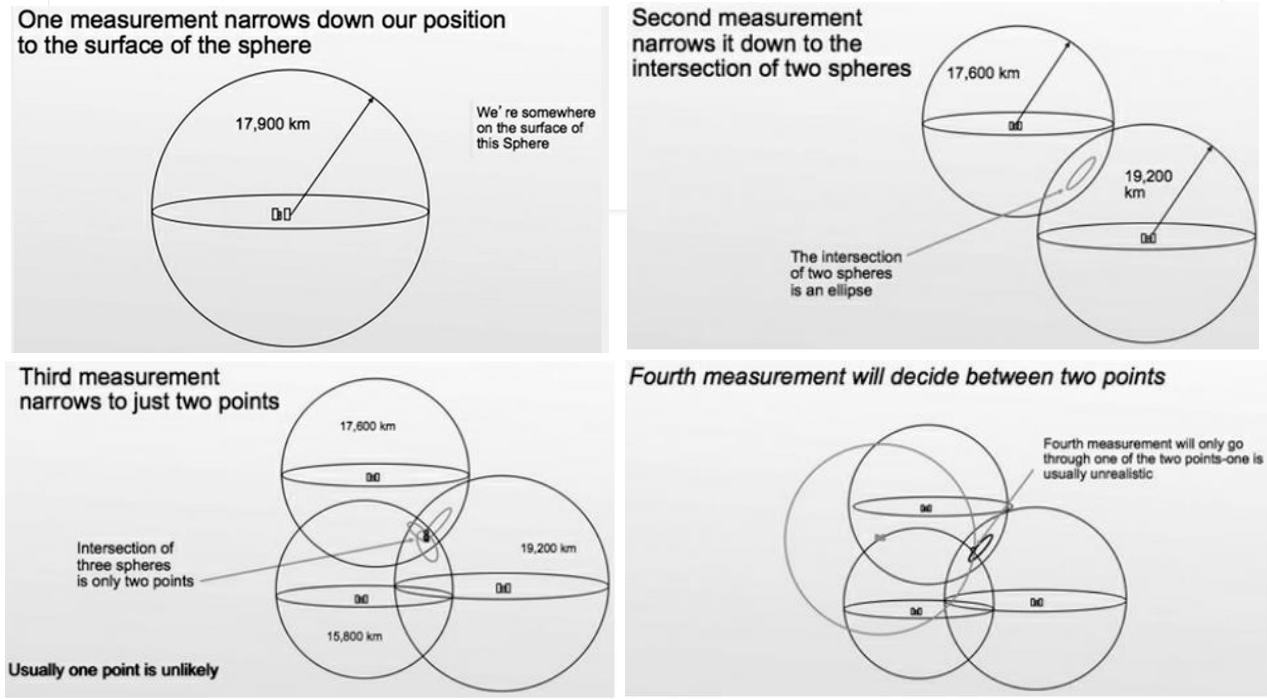
13

13

The user segment

- GPS makes use the time of arrival (*TOA*) of a GPS signal
- The satellite has a known position in space
  - Sends out a signal to a receiver on the earth's surface
  - The time interval (*signal propagation time*) is multiplied by the speed of the signal to give the satellite-to-receiver distance
  - By measuring the signal propagation time from multiple satellites, the receiver can determine its position by means of space resection.

14



15

The user segment

- Precise tracking of the positions of all the satellites in the constellations
- Extremely accurate time measurements and synchronization
- Geodetic computations
- Computation of errors
  - clock errors; orbit errors; receiver noise; atmospheric effects

16

16

The user segment

- GPS receiver can be employed as a stationary or mobile unit
  - Stationary – Static data collection
  - Mobile – Kinematic data collection

- Single receiver static point positioning can give an accuracy of 5 to 10m

17

17

The user segment

- Kinematic point positioning e.g. vehicle tracking 10 -100m
- Static relative positioning (two stationary receivers, commonly used by surveyors for distance measurement): 0.1 ppm -1 ppm (part per million)

18

18

The user segment

- Differential GPS (DGPS)
  - Two GPS receivers are required
    - one at a base that is precisely known
    - the other receiver is moving from one location to another
  - Code Pseudoranges (distance + error) caused by a lack of synchronization between the satellite and receiver clocks are recorded.
  - The base station then calculates the corrections and transmits them to the roving receiver

19

19

The user segment

- DGPS has been improved by the establishment of Continuously Operating Reference Stations (CORS)
  - Stations are permanent GPS receivers
  - Anyone working within a distance range from these stations can receive the corrections transmitted via the radio beacons
  - In Canada
    - Canadian Active Control System (CACS)
    - B.C. Active Control System
    - Can-net (commercial)

The user segment

- Real-time Kinematic GPS
  - This DGPS where the corrections are sent to the rover in Realtime
  - When the roving receiver is connected to an active control station, one is using RTK GPS

  - **What if you have a base station and a rover but you don't know the coordinates of the base station?**

GPS Signals

- The generated signals on board the satellites are derived from a fundamental frequency =10.23 MHZ
  - Two carrier signals in the L-band, denoted L1 and L2, are generated by integer multiplications of the fundamental frequency
  - L1 and L2 are modulated by codes to provide satellite clock readings to the receiver and transmit information such as the orbital parameters.
  - The codes consist of a sequence with the states +1 or -1, corresponding to the binary values 0 or 1.
  - The signals then go through biphase modulation by performing a 180° shift in the carrier phase whenever a change in the code state occurs

22

22

GPS Signals – biphase modulation

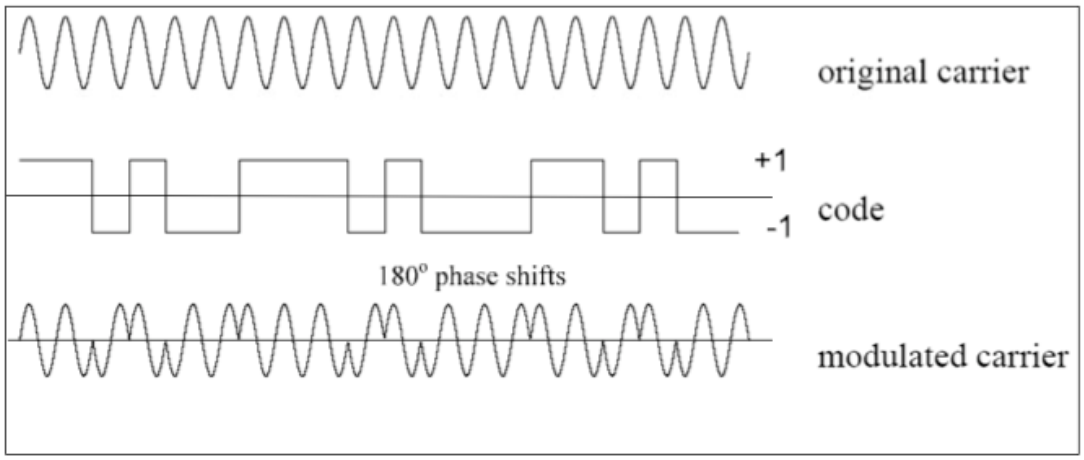


Image: Alain L. Kornhauser (2006), Global Navigation Satellite System (GNSS)

23

23

GPS Accuracy

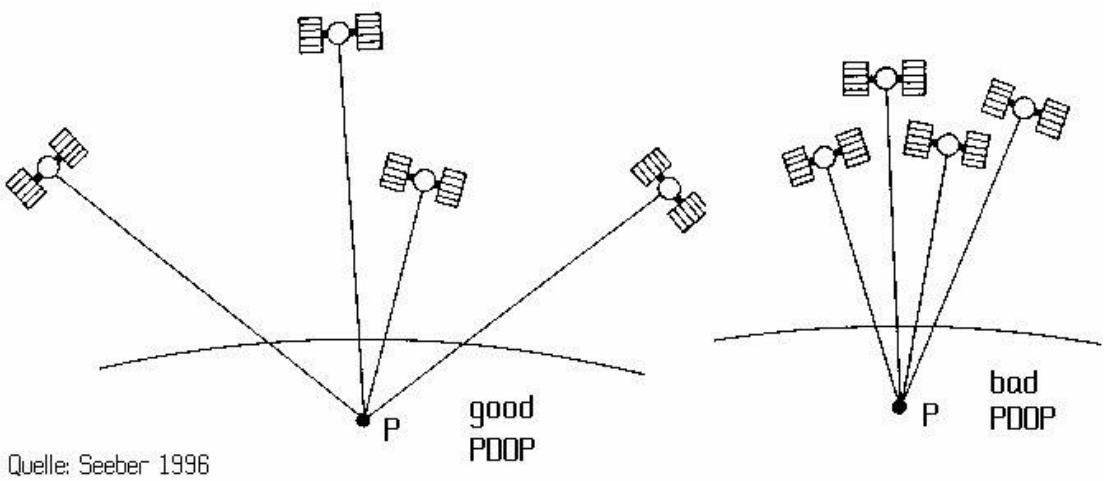
- The accuracy of the system is determined by several factors.
  - accuracy of the atomic clocks
  - ephemeris error (how certain we are of the exact position of the satellites)
  - atmospheric errors
  - relativistic timing adjustments
  - receiver error (how the receiver software computes the location)
  - Multipath interference

GPS Accuracy

- The atmosphere, both the ionosphere and troposphere, can bend GPS signals, making the satellites appear farther away than they are, thus causing error.
- The precise location of the satellites satellites is important yet the broadcast ephemeris data may not always accurately reflect their true position
- Multi-path interference is caused in urban areas, where the GPS signals can be reflected or bounce off of large buildings, creating errors in the computed position
- Selective availability was the intentional inclusion of both time and ephemeris data errors, in order to reduce the precision of the civilian GPS signals.
  - It has been since removed
  - DGPS was designed, mainly, with this problem in mind

Dilution of Precision

- The geometry of the satellites used in computing our position is also very important.
- The effect of the geometry of satellites is referred to as the Dilution of Precision, or DOP
- DOP can be expressed as a measure of different componets
  - horizontal (HDOP)
  - vertical (VDOP)
  - 3D position (PDOP)
  - time (TDOP)
  - geometric (GDOP)
- PDOP indicates the quality of the solution with respect to satellite geometry



Quelle: Seeber 1996

http://www.arboris.de/online_help/_0za0u86sw.htm

Wide Area Augmentation System (WAAS)

- WAAS is a satellite-based augmentation system
  - Augments or enhances the integrity and accuracy of standard GPS capability
  - developed to provide accurate navigation for commercial aircraft; also works for hand-held receivers
  - developed because the standard civilian GPS signal does not meet aviation requirements for accuracy, integrity and availability.
  - provides corrections over broad areas with accuracies to less than 3 m precision 95 % of the time.

28

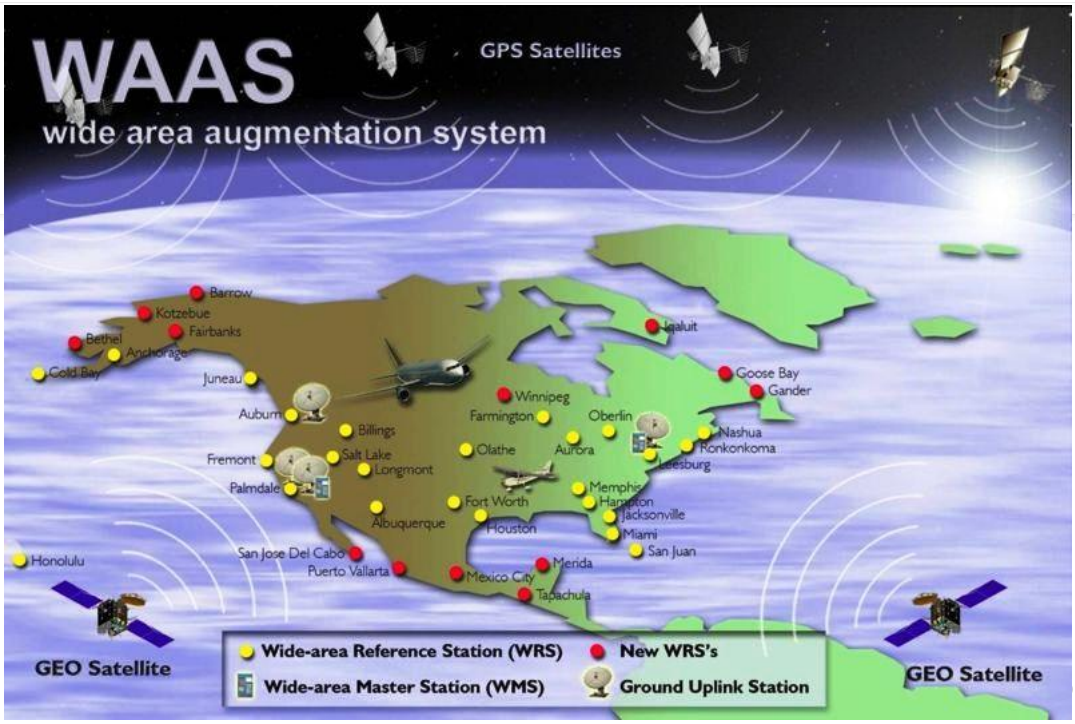
28

Wide Area Augmentation System (WAAS)

- WAAS uses geo-stationary satellites to receive data measured from many ground stations, and it sends information to GPS users for position correction.
  - 38 ground stations across North America (Canada, US, Mexico, Puerto Rico)
  - 3 master control stations determine the regional offset, which is then uplinked through four ground uplink stations
  - It is then broadcast from two commercial geostationary satellites to aircraft and ground receivers throughout North America.
  - Since WAAS satellites are geo-stationary type, the Doppler frequency caused by their motion is very small. Thus, the signal transmitted by the WAAS can be used to calibrate the sampling frequency in a GPS receiver.

29

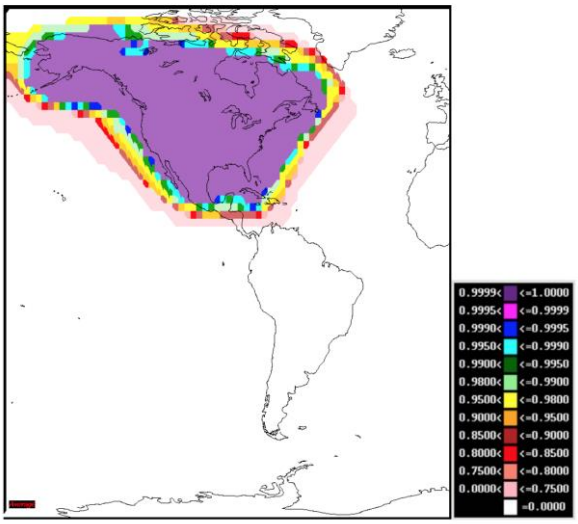
29



30

WAAS

- Local precision availability
- Colors correspond to levels of service availability



Source: https://www.gps.gov/technical/ps/2008-WAAS-performance-standard.pdf

31

31

Wide Area Augmentation System (WAAS)

- The WAAS system operates in North America
- There are several compatible international systems
  - European Geostationary Navigation Overlay Service (EGNOS),
  - Japanese Multi-functional Transport Satellite based Satellite Augmentation System (MSAS),
  - Russian SDCM (System for Differential Corrections and Monitoring) system
  - Indian GPS And Geo-Augmented Navigation (GAGAN)
  - China's Beidou includes this capability within its basic design and does not require a separate augmentation system

32

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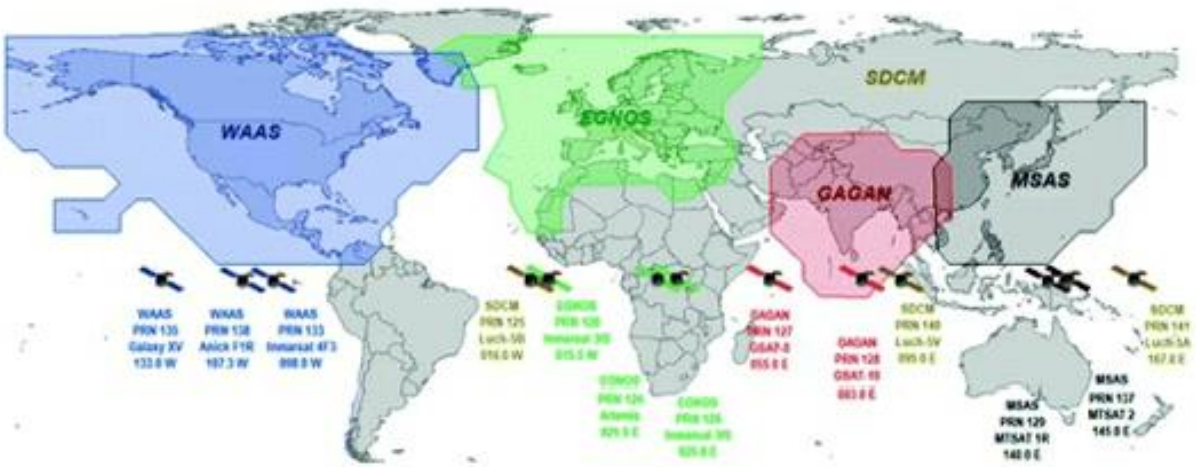

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33