Image from NASA:
https://commons.wikimedia.org/wiki/File:Earth_Western_Hemisphere_transparent_background.png#filelinks

GIScience

Global Navigation Satellite Systems

WV VIEW

AmericaView℠
Empowering Earth Observation Education
AmericaView.org - Est. 2003

Navigation Before GNSS

https://commons.wikimedia.org/wiki/File:USN_Midshipman_takes_a_sextant_reading.jpg

Global Navigation Satellite Systems (GNSS)

- Satellite-based
- Relative to a datum
- Can be very accurate

- Geodesy = The science of measuring the shape of the Earth and locations on or in the Earth.

Global Navigation Satellite Systems (GNSS)

GPS	Glonass	Galileo	BeiDou
G01	R01	E01	C01
G02	R02	E02	C02
G03	R03	E03	C03
G04	R04	E04	C04
G05	R05	E05	C05
G06	R06	E07	C06
G07	R07	E08	C07
G08	R08	E09	C08
G09	R09	E12	C09
G10	R10	E14	C10
G11	R11	E18	C11
G12	R12	E19	C12
G13	R13	E24	C13
G14	R14	E26	C14
G15	R15		C17
G16	R16		C19
G17	R17		C20
G18	R18		C21
G19	R19		C22
G20	R20		C27

- NAVSTAR = United States
- GLONASS = Russia
- Galileo = European Union
- Compass (BeiDou-2) = China
- QZSS = Japan
- IRNSS = India

http://gnssmissionplanning.com/

Components of NAVSTAR GPS

https://commons.wikimedia.org/wiki/File:GPS_Satellite_NASA_art-iif.jpg

- Satellite Segment = Constellation of satellites orbiting and transmitting positional signals
- Control Segment = Tracking, communications, data gathering, integration, analysis, and control facilities
- User Segment = Individual with one or more receivers
- GNSS Receiver = A device that records data transmitted by each satellite/process data to 3D coordinates

NAVSTAR GPS Satellites

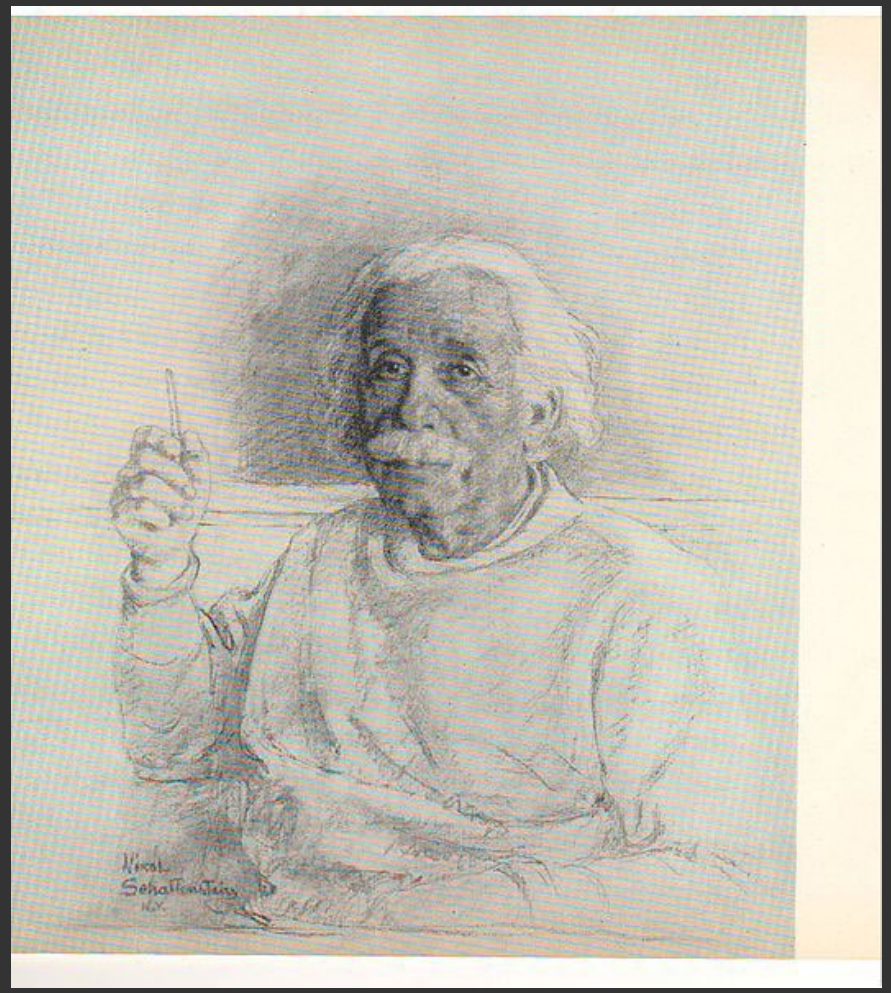
- Altitude ≈ 20,000 kilometers (12,427 miles)
- Orbits = 6
- Daily Orbit = Twice
- Time Above Horizon = 8 or more hours daily
- Typically, there are more than 24 in orbit at one time

https://commons.wikimedia.org/wiki/File:GPS-constellation-3D-NOAA.jpg

Ground Stations

- Master Station = Colorado Springs
- Number of Stations = 5 tracking stations (Colorado Springs, Hawaii, Ascension, Diego Garcia, Kwajalien)
- Purpose = Observe, maintain, manage, and communication
- Data = Satellite health and status, tracking information, timing
- Master Station Purpose = Synthesizes information and broadcasts navigation, timing, and other data to each satellite/signal for course corrections, changes in operation, or other maintenance

How it Works



https://commons.wikimedia.org/wiki/File:Einstein,_Albert.JPG

- Range Distance = Distance between 2 objects
- Satellite to Receiver
- Range = speed of light X travel time
- Speed of light is a constant
- Also requires timing information
- Relies on radio signals

$$\text{Velocity} = \frac{Distance}{Time}$$

$$\text{Time} = \frac{Distance}{Velocity}$$

Distance = Velocity X Time

How it Works: 3D Trilateration

- Need at least 4 overlapping spheres
- Can use three satellites and the Earth
- Generally, more satellites equals greater positional accuracy

How it works

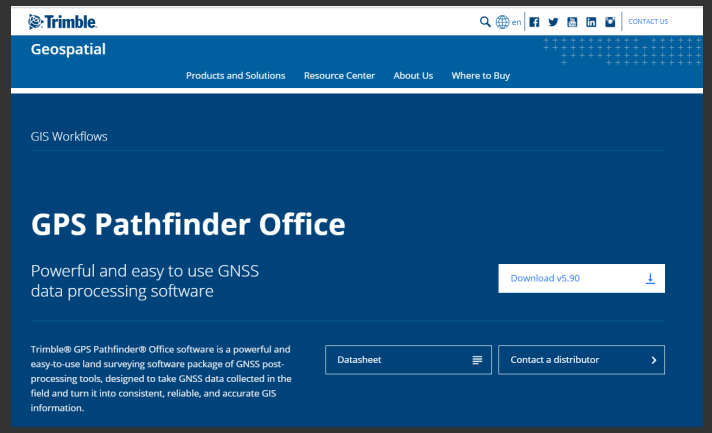
- Channels = relates to number of satellites that can be detected (12-channel can record up to 12)
- Single Frequency = only picks up L1
- Dual Frequency = picks up L1 and L2
- Ephemeris = data referring to the GPS satellite's position in orbit
- Almanac = data concerning the status of a GPS satellite, which is included in the information being transmitted by the satellite
- C/A Code = the digital code broadcasted on the L1 frequency, which is accessible by all GPS receivers
- P Code = the digital code broadcasted on the L1 and L2 frequencies, which is accessible by the military
- Y Code = an encrypted version of the P code

GPS Datums

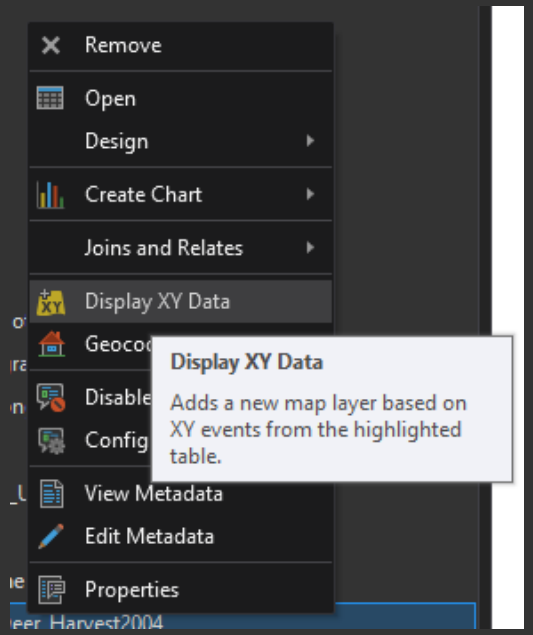
- Location and elevation data are provided relative to a datum and in defined units
- Datum Examples:
  World Geodetic System 1984 (WGS84)
  North American Datum 1983 (NAD83)
  North American Datum 1927 (NAD27)
- It is important to know the datum information!

- Latitude/Longitude
  Degrees, Minutes, Seconds
  Degrees, Decimal Degrees
- UTM
  Easting/Northing
- Elevation
  Feet
  Meters

GIS and GPS

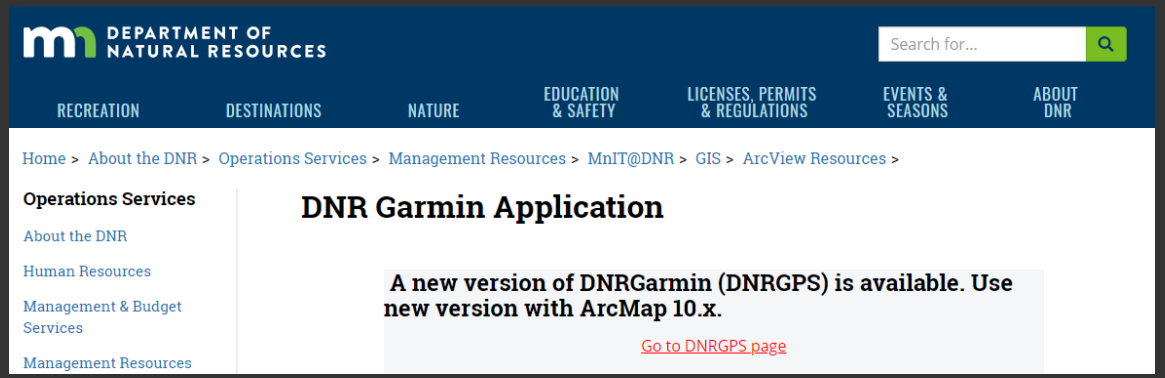


https://geospatial.trimble.com/products-and-solutions/gps-pathfinder-office



How do I get points into my GIS?

1. MxGPS
2. Minnesota DNR Garmin Application
3. Conversion Software
4. Manipulate waypoints in Excel
5. Display XY Data
6. Trimble Software

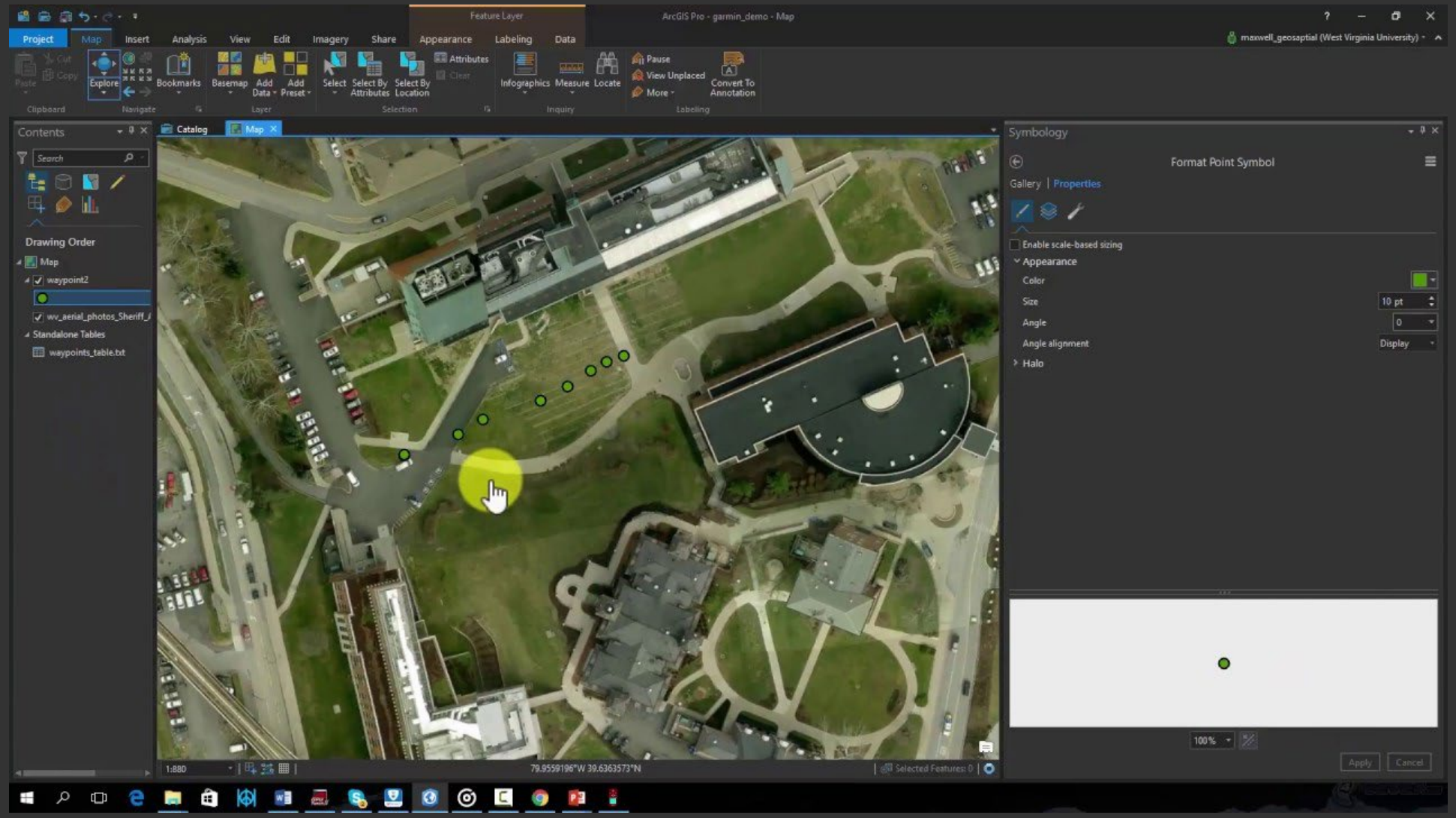


https://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html

Things to Consider

- Must know your datum and units
- Must define datum and units correctly
- May need to manipulate data

Video: Minnesota DNR Garmin Application



Types of Data

- Waypoints = individual, unconnected point locations (x, y, z)
- Tracks = points connected to form lines
- Routes = a series of points that you want to navigate between

Positional Uncertainty

- There is noise/error/uncertainty with all range measurements
- Spheres will not meet at a single point
- Fuzziness

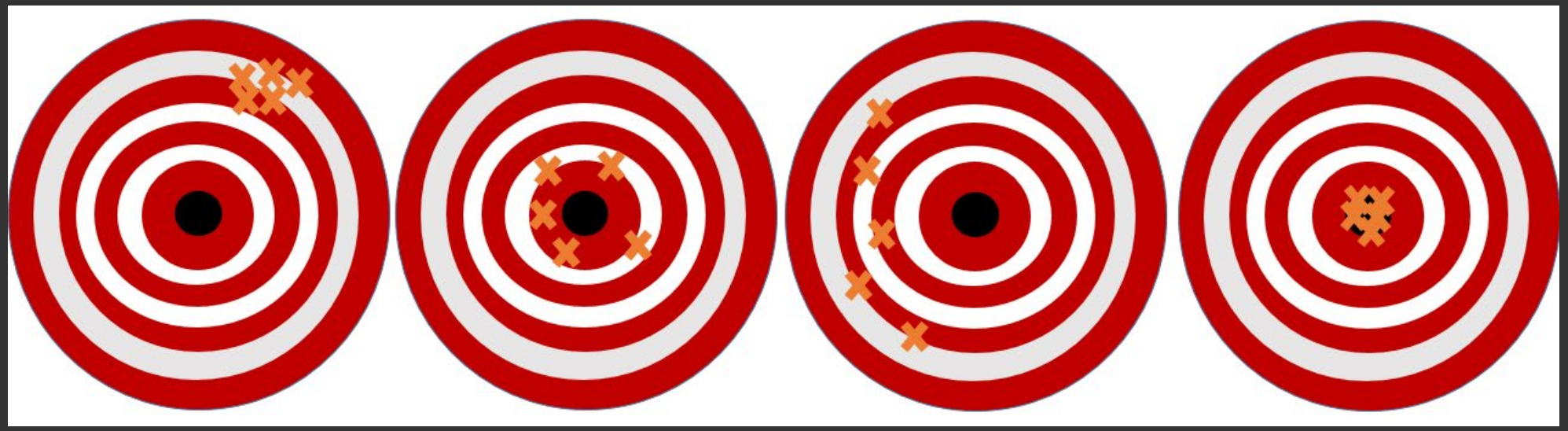
Sources of Uncertainty

- Ionospheric and atmospheric delays
- System operation delays
  - Satellite tracking
  - Time and signal delays
  - Loss of sync
- Receiver
- Reflection of signals (multipath)
- Topography
- Canopy cover
- Weather
- Lack of satellite reception
- Movement

Accuracy vs. Precision

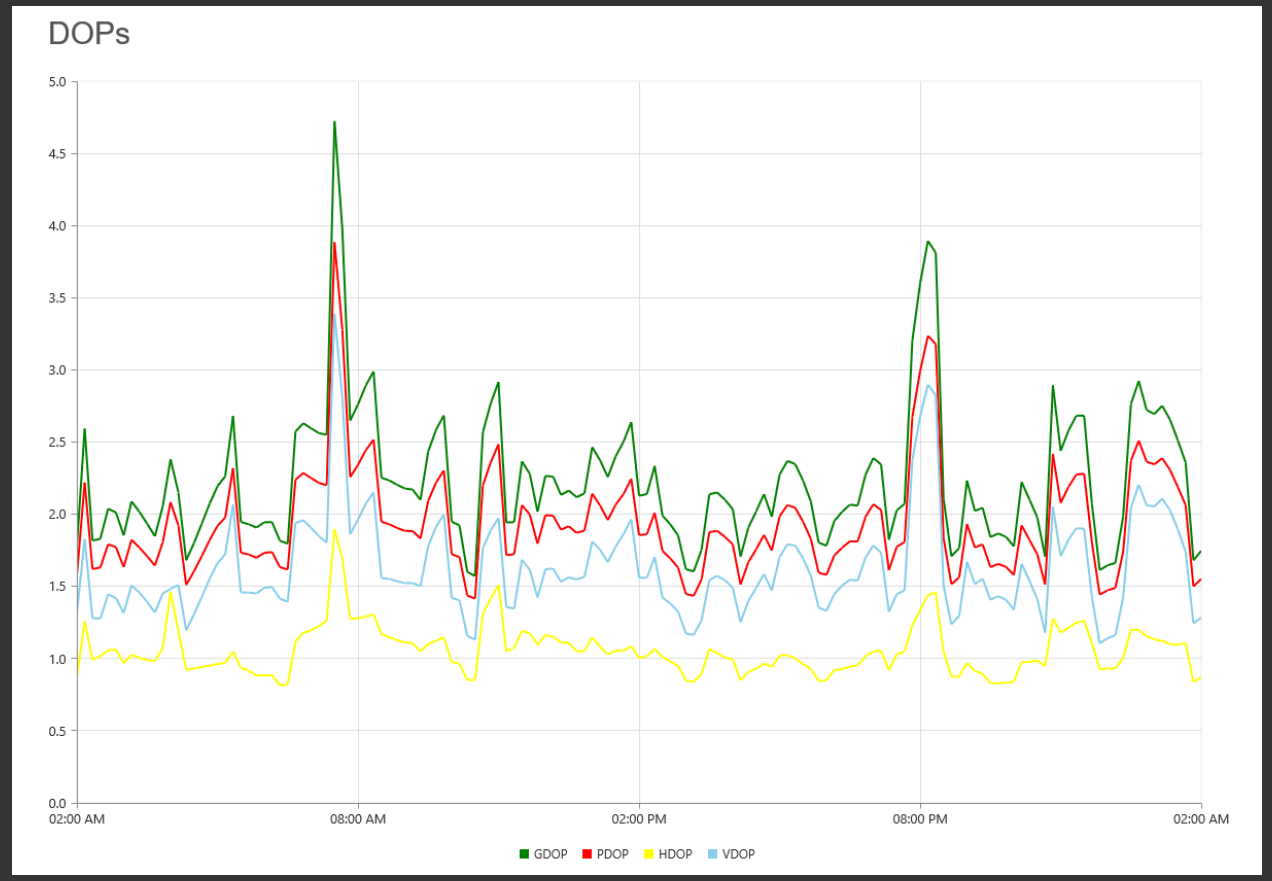
Accuracy = agreement with truth

Precision = agreement with other measurements



Measuring Uncertainty based on Satellite positon: Dilution of Precision

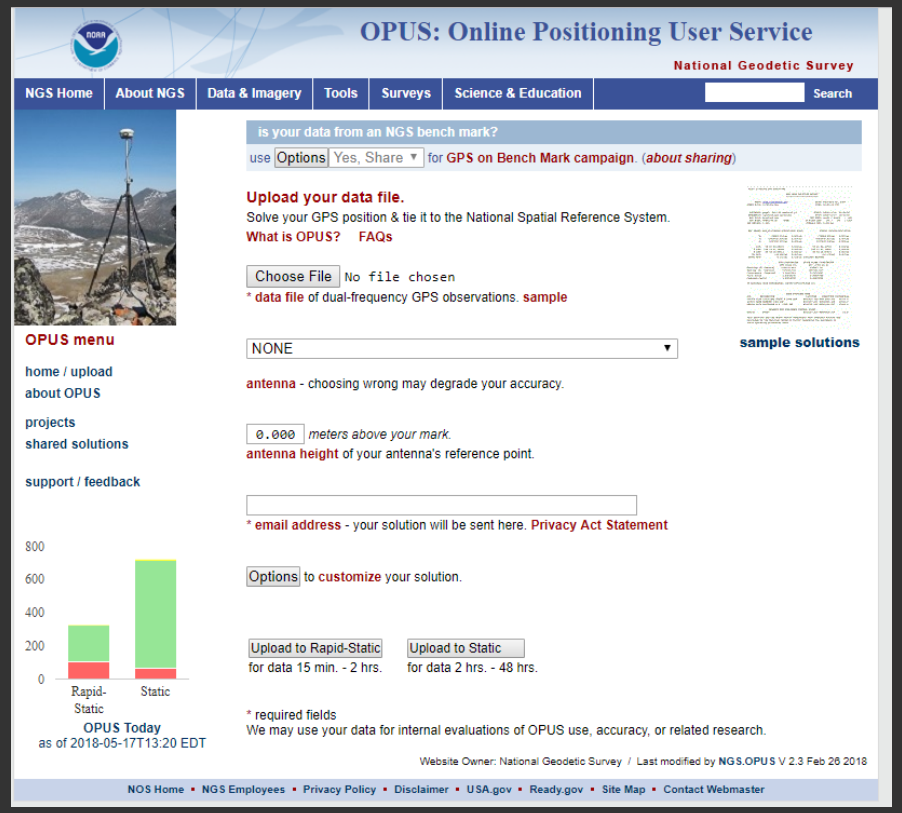
- A measure of positional precision
- Horizontal Dilution of Precision (HDOP)
- Vertical Dilution of Precision (VDOP)
- Positional Dilution of Precision (PDOP)
- PDOP = Ratio of the volume of a tetrahedron created by the four most widespread, observed satellites to the volume defined by the ideal tetrahedron
- Generally, better precision is obtained when the satellites are more spread out in the local sky
- Lower PDOP is better
- DOP spikes are bad



http://gnssmissionplanning.com/

Increasing Precision

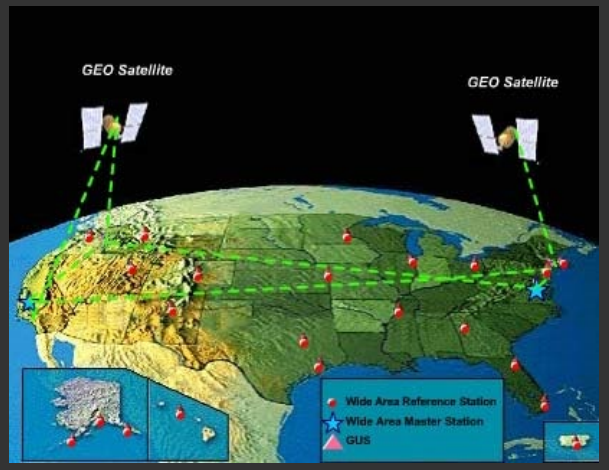
- Collect multiple stationary measurements
  - Not an option for moving objects
  - Can get statistics
- Make use of GLONASS
- Use WAAS enabled unit
- Utilize Differential Correction
  - Post-Processing
  - Real-Time Differential GPS, Real-Time Kinematic (RTK)

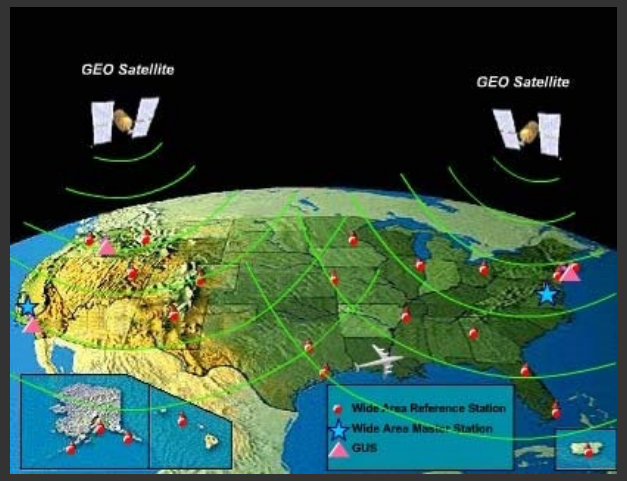


https://www.ngs.noaa.gov/OPUS/

Wide Area Augmentation System (WAAS)

- Satellite-Based Augmentation System (SBAS)
- U.S. Federal Aviation Administration
- Real-time accuracies for single fixes
- Within 4-7 meters
- Can average multiple fixes for increased accuracy
- Correlated relative to broadcasted correction data from ground stations
- Only for NAVSTAR GPS (US System)
- Most handheld units are WAAS enabled
- For real-time needs

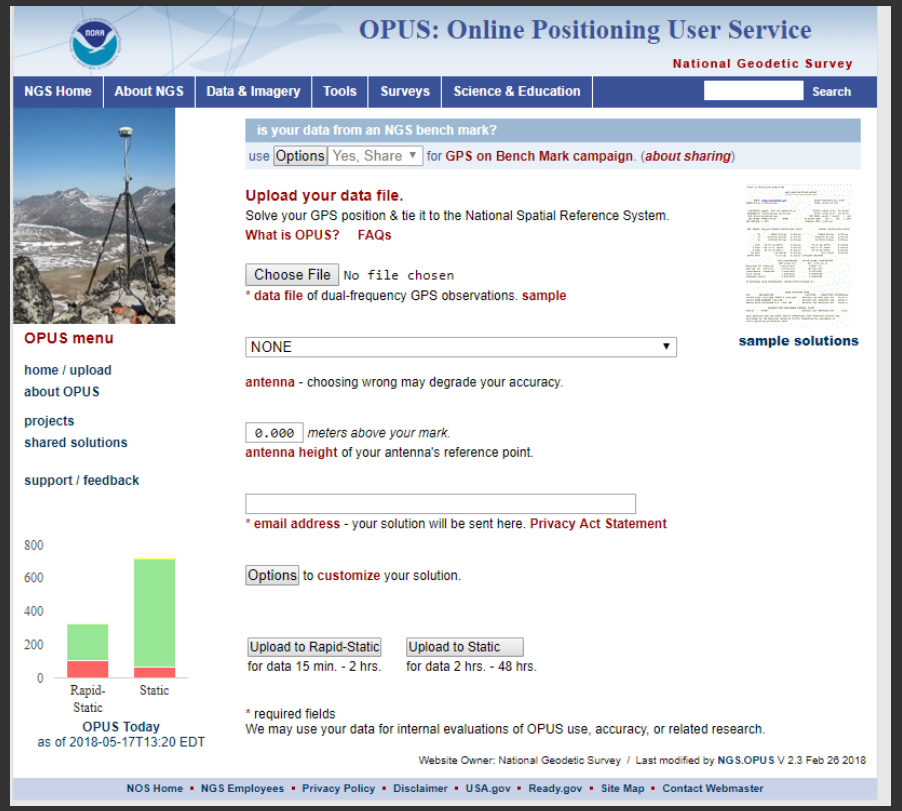




https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/waas/howitworks/

Post-Processing

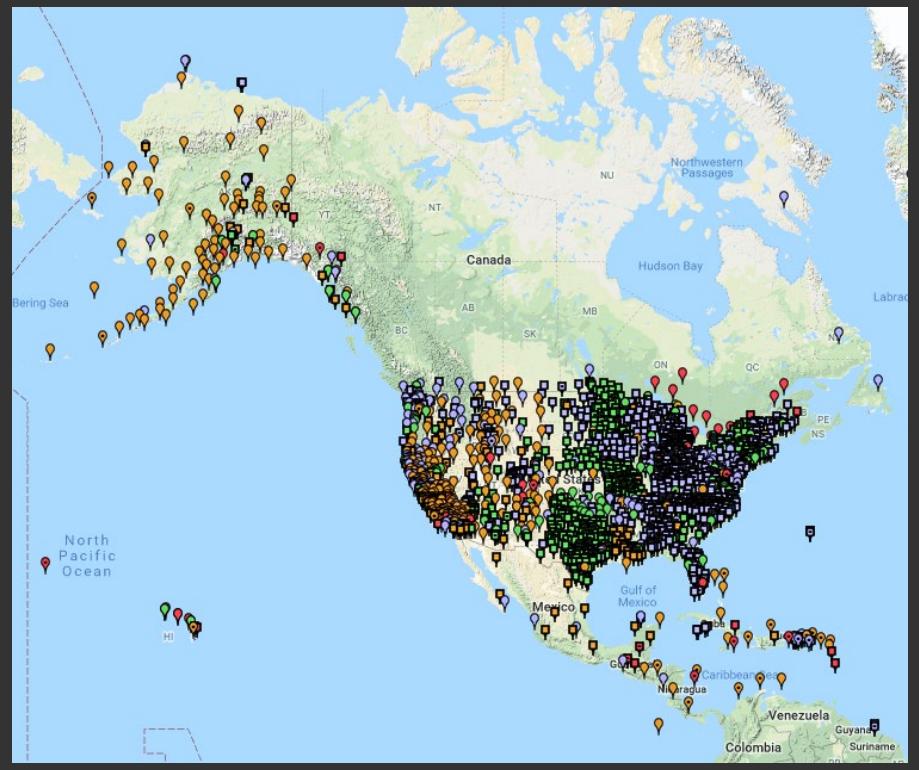
- Based on comparison to noise or error at known points (a differential correction)
- Correction applied after raw GPS data are collected
- Can be correct relative to established GPS points (OPUS points from the National Geodetic Survey or CORS data)
- Can be corrected relative to you own base station
- Not useful if you need precise data ahead of time
- Requires specialized software
- Can now correct using cell phone signals



https://www.ngs.noaa.gov/OPUS/

Continuously Operating GPS Reference Stations (CORS)

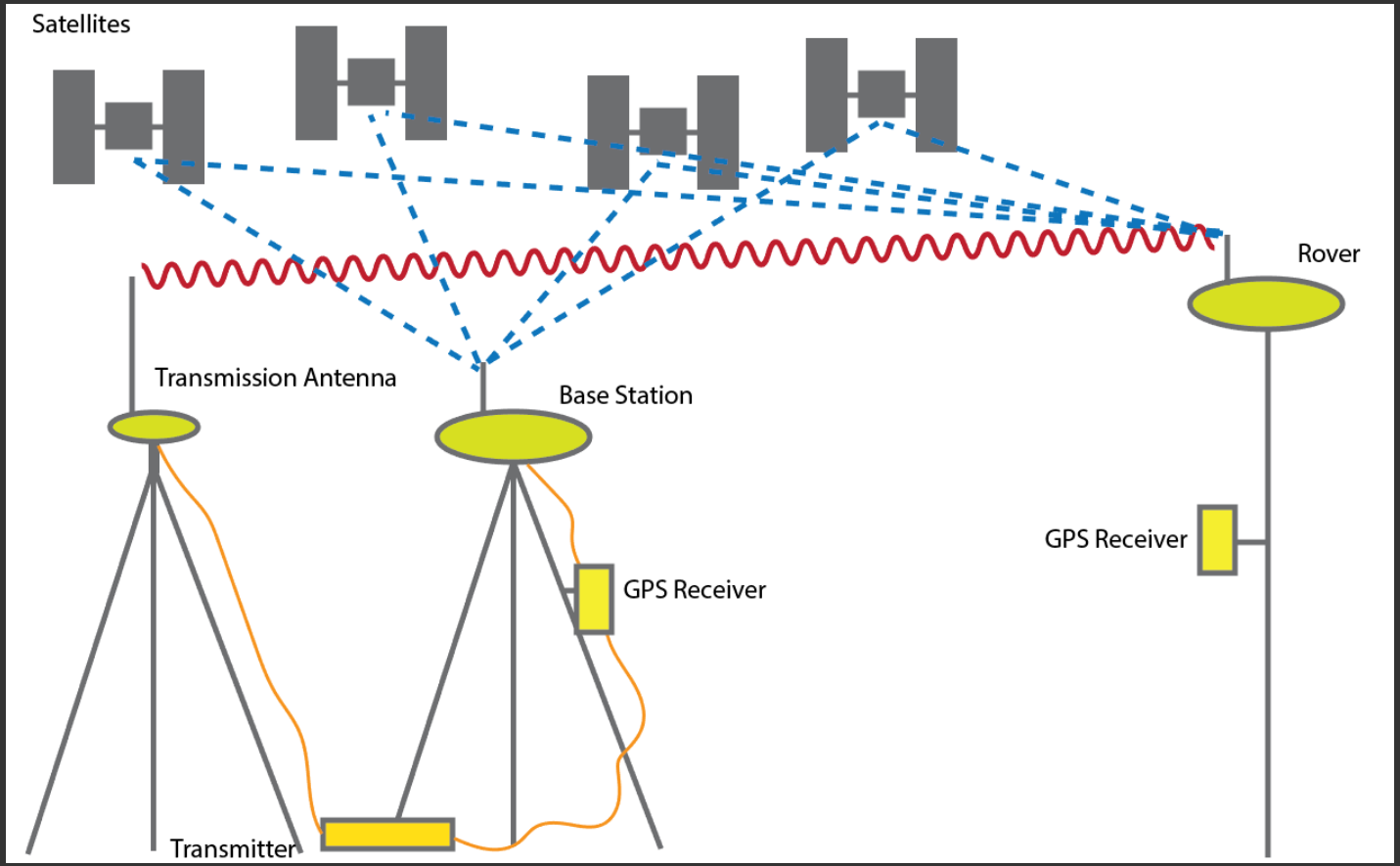
- Highly accurate/precise reference locations for comparison



https://geodesy.noaa.gov/CORS/

Real-Time Kinematic (RTK)

- GPS data are collected with a rover
- Correction are made using a base station
- Corrections are transmitted from base station to rover



Base Stations

https://commons.wikimedia.org/wiki/File:CORS_spicewood_lcrh.jpg

- Survey-grade quality GPS unit
- If GPS data are continuously collected at a location for at least two hours, the location is considered a highly precise/accurate reference location

Accuracy Comparisons

- Horizontal measurements are more accurate/precise than vertical
- One report:
  - Non-corrected = < 10 m horizontal
  - WAAS = 0.3 – 2 m horizontal
  - RTK = 0.05 – 0.5 m horizontal
  - Post-Processed = 0.02 – 0.25 m horizontal
- Accuracy varies with collection conditions
- Depends on project needs and budget

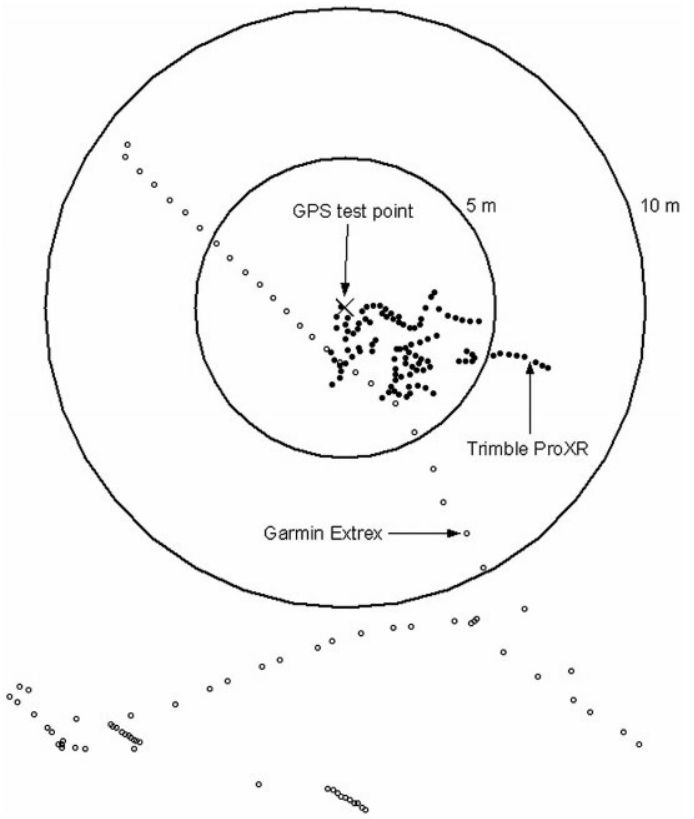


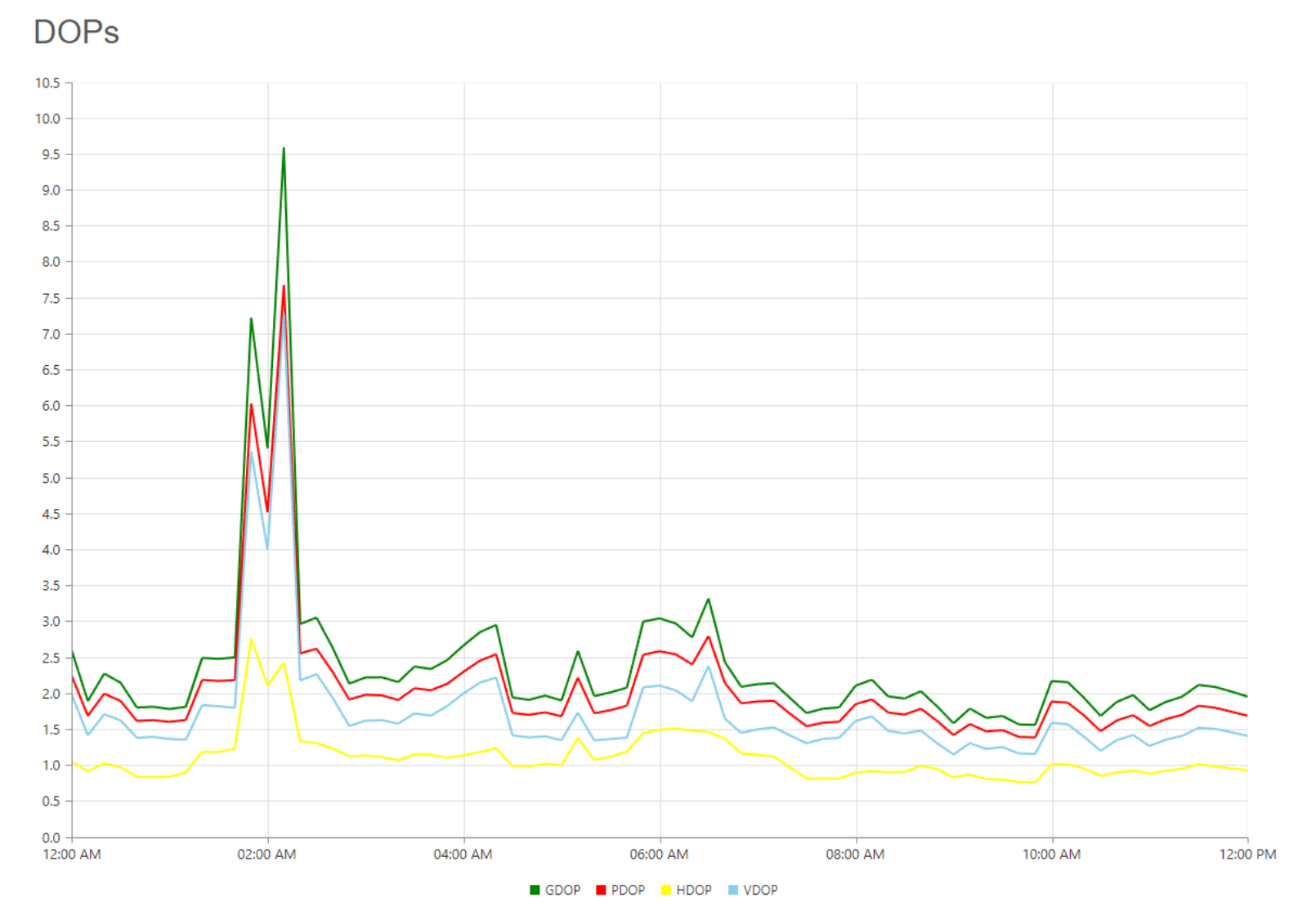
Figure 5. Sample spread of fixes collected for two GPS receivers at low slope position.

Danskin, S.D., Bettinger, P., Jordan, T.R., and C. Cieszewski (2009). "A comparison of GPS performance in a southern hardwood forest: exploring low-cost solutions for forestry applications." *Southern Journal of Applied Forestry*, 33(1): 9-16.

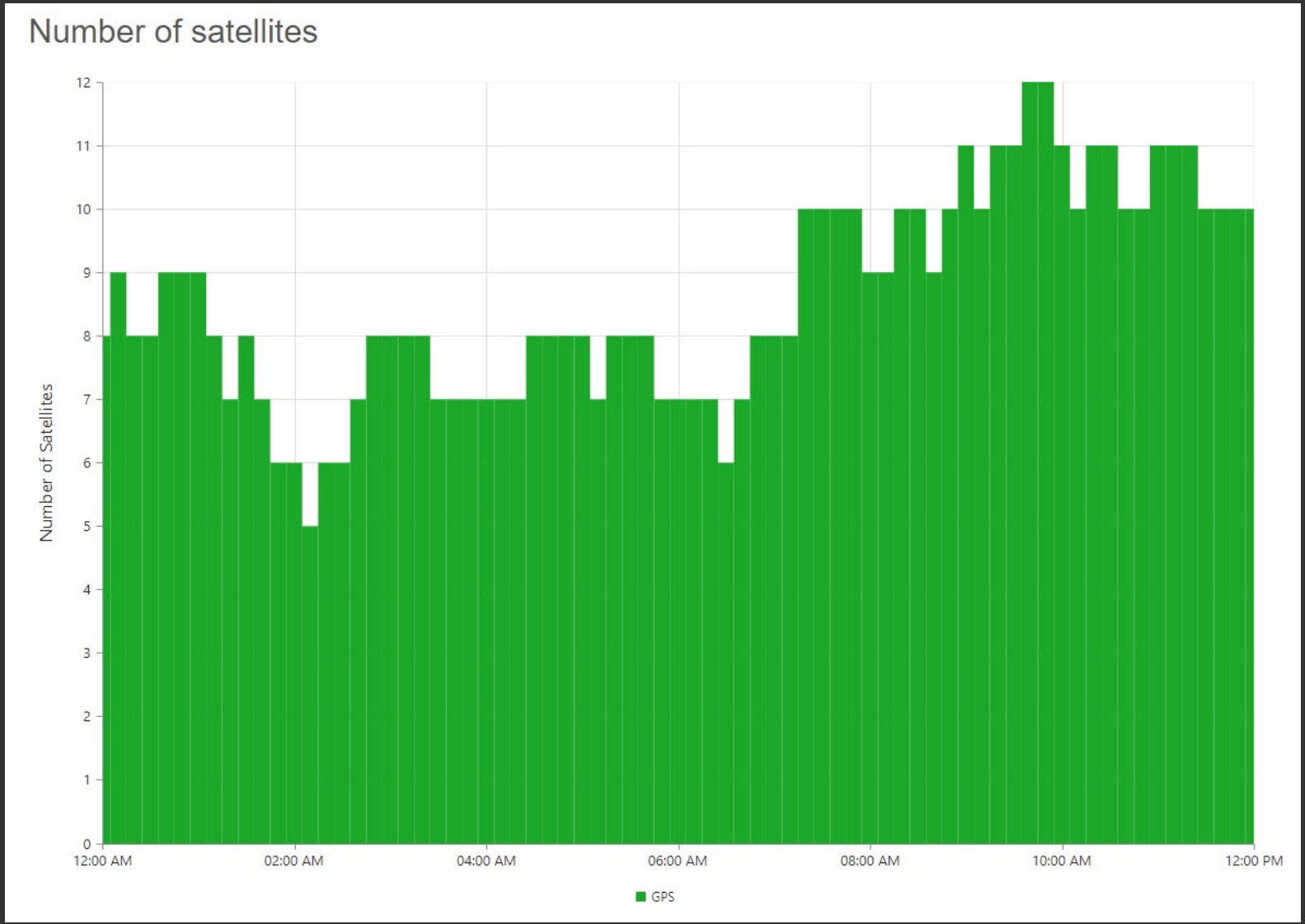
Mission Planning

- Since we know where the satellites will be ahead of time, we can plan ahead of data collections.
- I like this software: http://gnssmissionplanning.com/

DOP

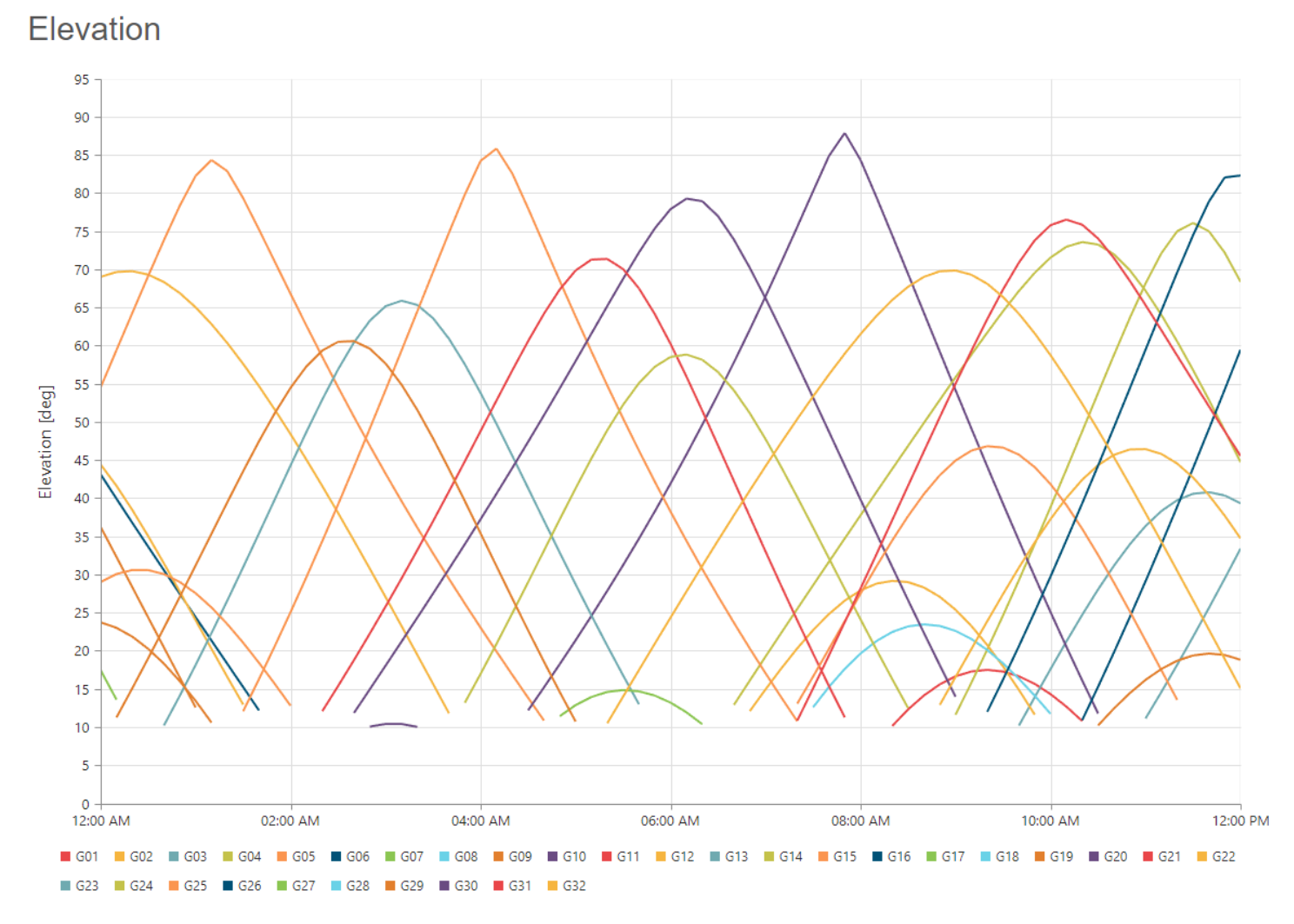

DOPs
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
12:00 AM
02:00 AM
04:00 AM
06:00 AM
08:00 AM
10:00 AM
12:00 PM
GDOP
PDOP
HDOP
VDOP

Number of Satellites

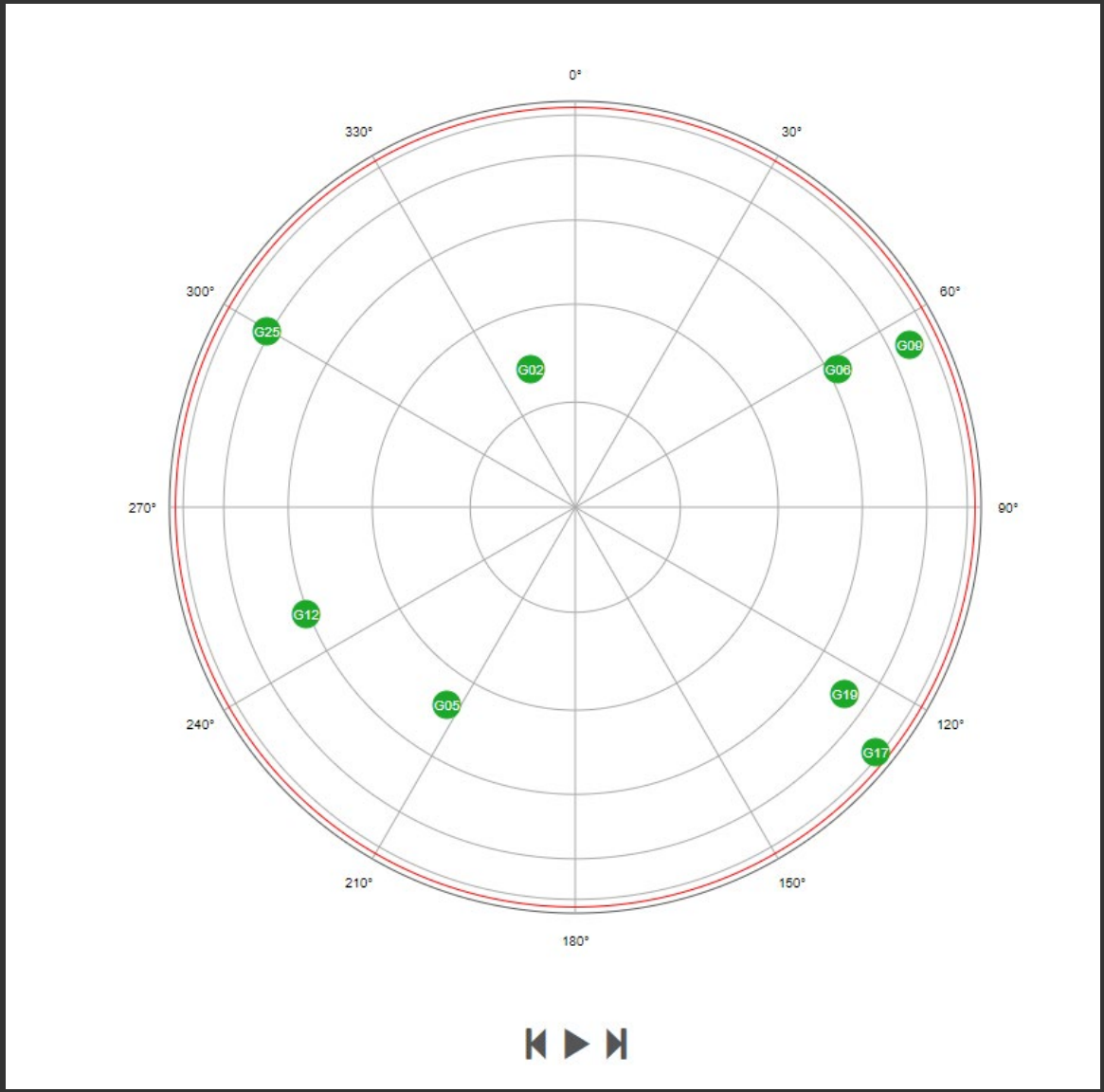


Satellite Visibility

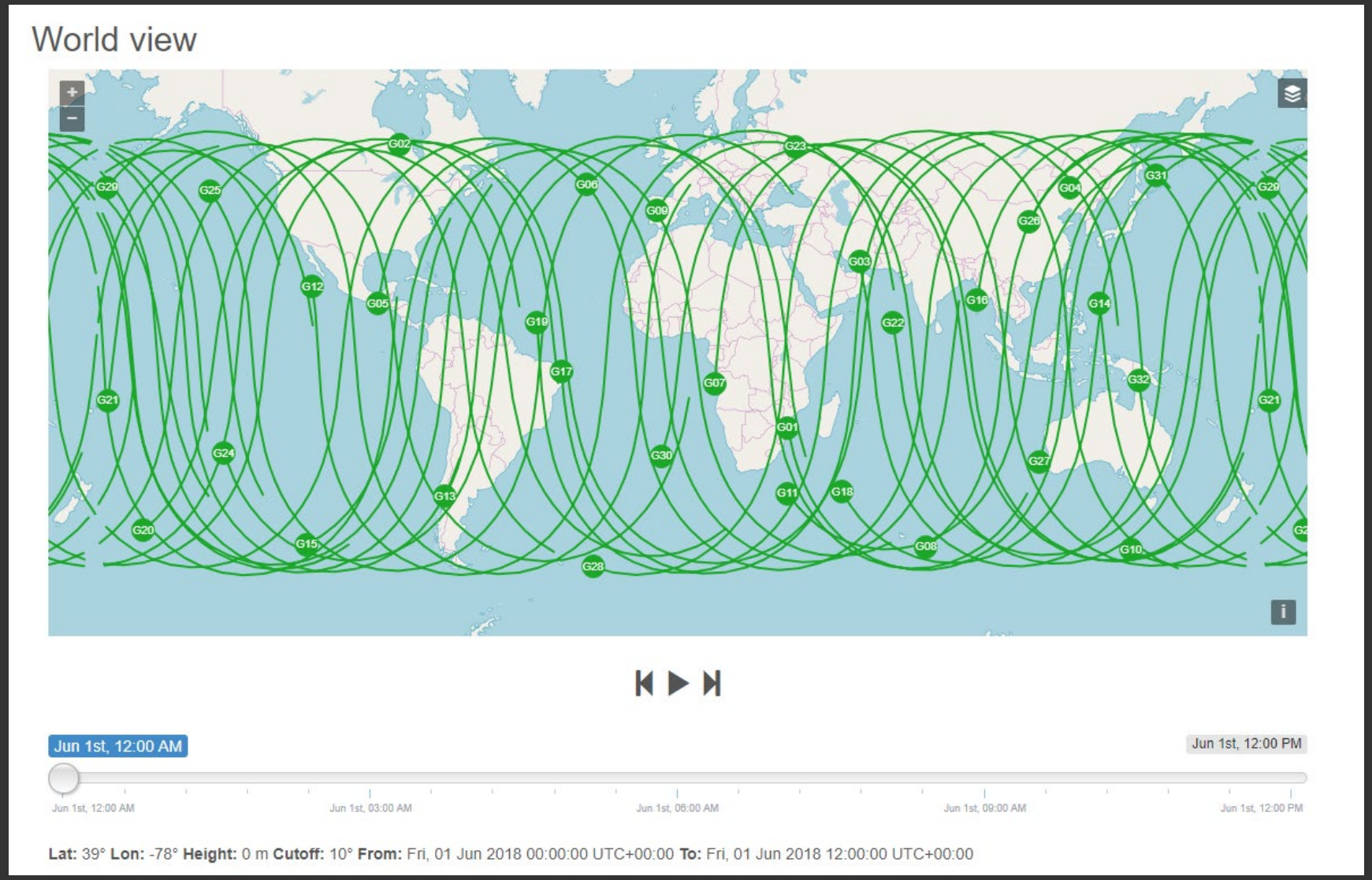
Satellite Elevation



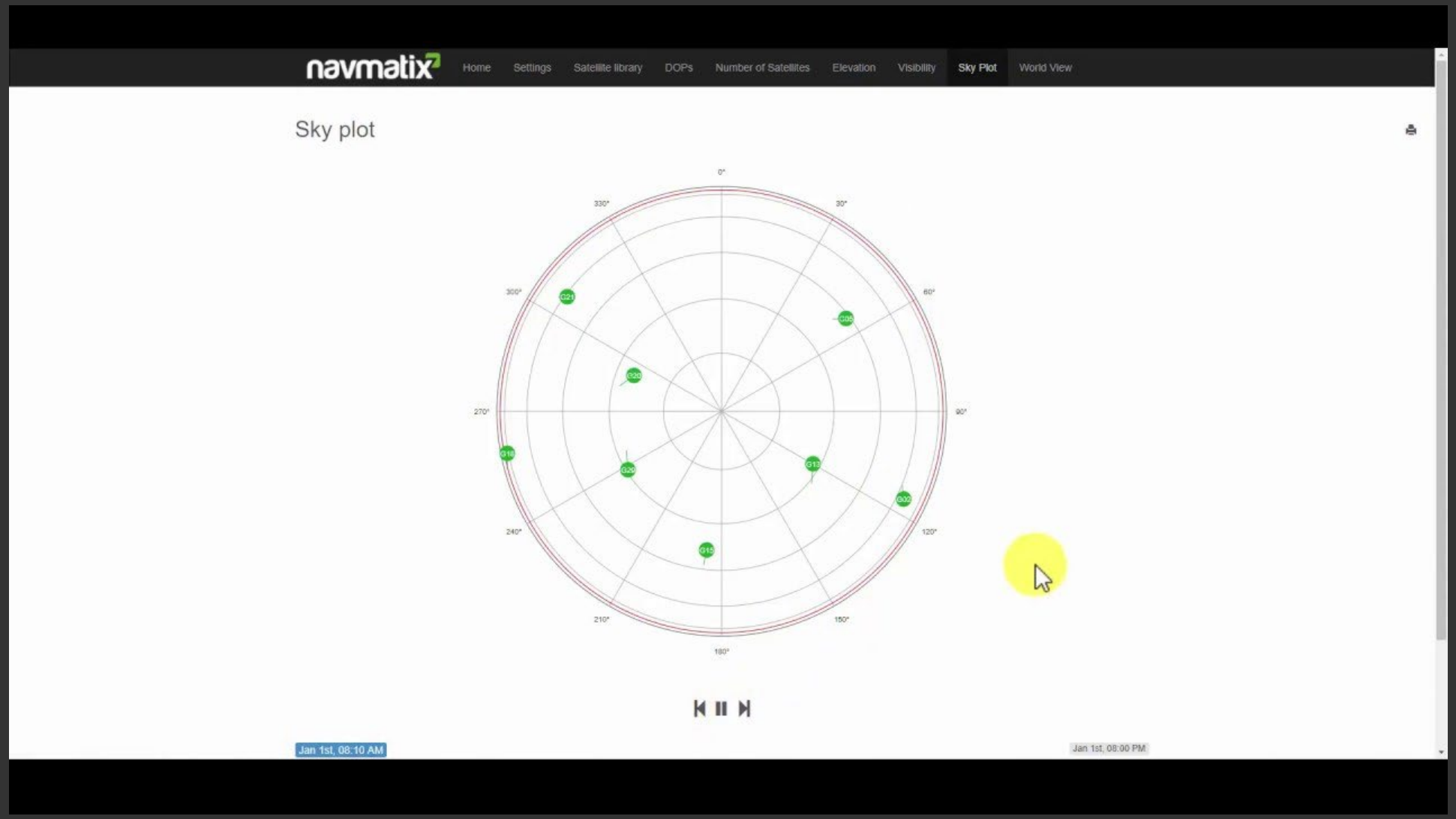
Sky Plot


0°
30°
60°
90°
120°
150°
180°
210°
240°
270°
300°
330°
G25
G02
G06
G09
G12
G05
G19
G17

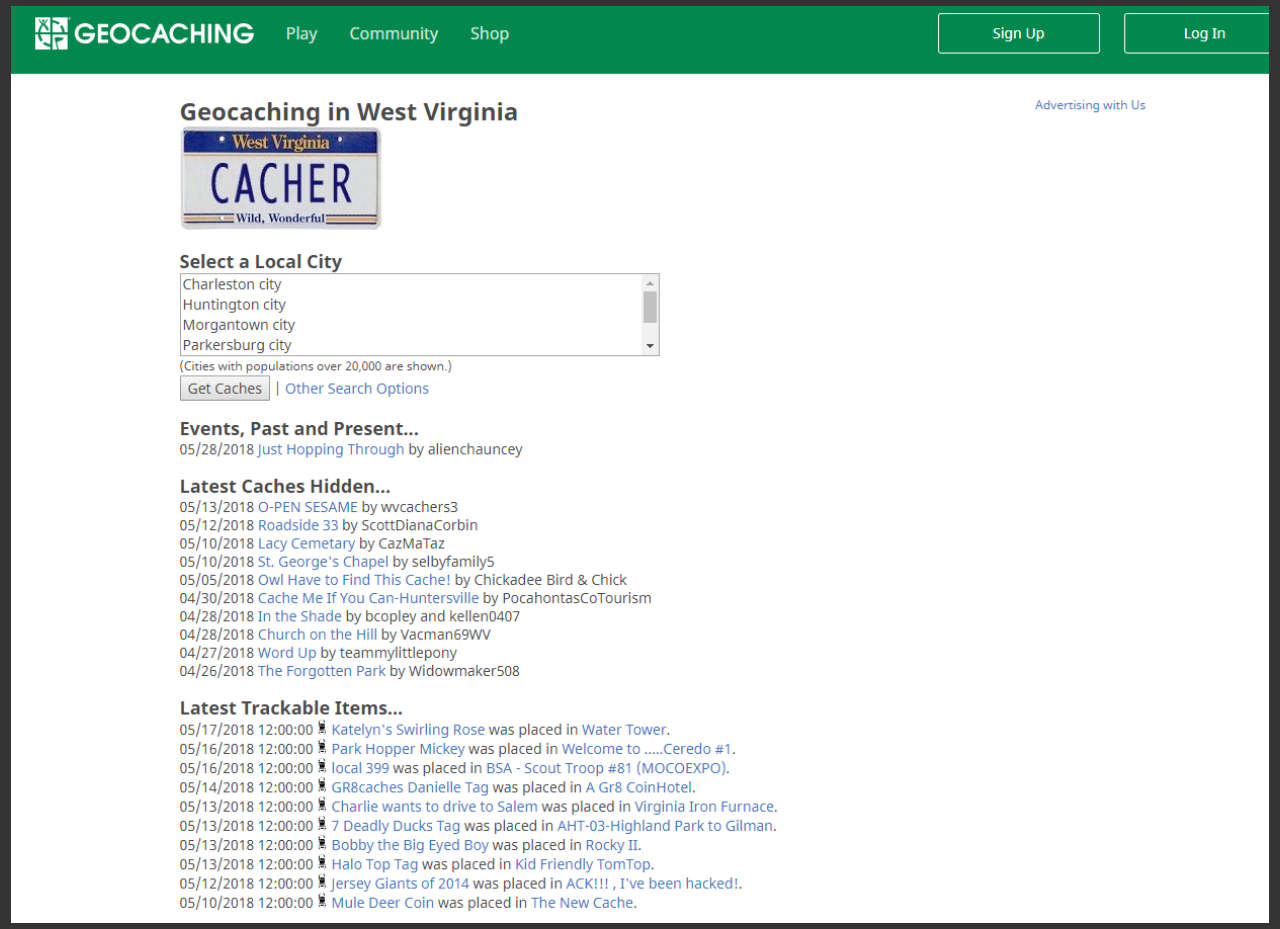
Sky Orbit


World view
G02
G23
G29
G25
G06
G09
G04
G31
G29
G26
G03
G12
G05
G16
G14
G19
G22
G17
G07
G32
G21
G21
G01
G24
G30
G27
G13
G11
G18
G20
G15
G08
G10
G28
Jun 1st, 12:00 AM
Jun 1st, 12:00 PM
Jun 1st, 12:00 AM
Jun 1st, 03:00 AM
Jun 1st, 06:00 AM
Jun 1st, 09:00 AM
Jun 1st, 12:00 PM
Lat: 39° Lon: -78° Height: 0 m Cutoff: 10° From: Fri, 01 Jun 2018 00:00:00 UTC+00:00 To: Fri, 01 Jun 2018 12:00:00 UTC+00:00

Video: GNSS Collection Planning



Geocaching



https://www.geocaching.com

This is the end of this lecture module.

Please return to the West Virginia View Webpage for additional content.