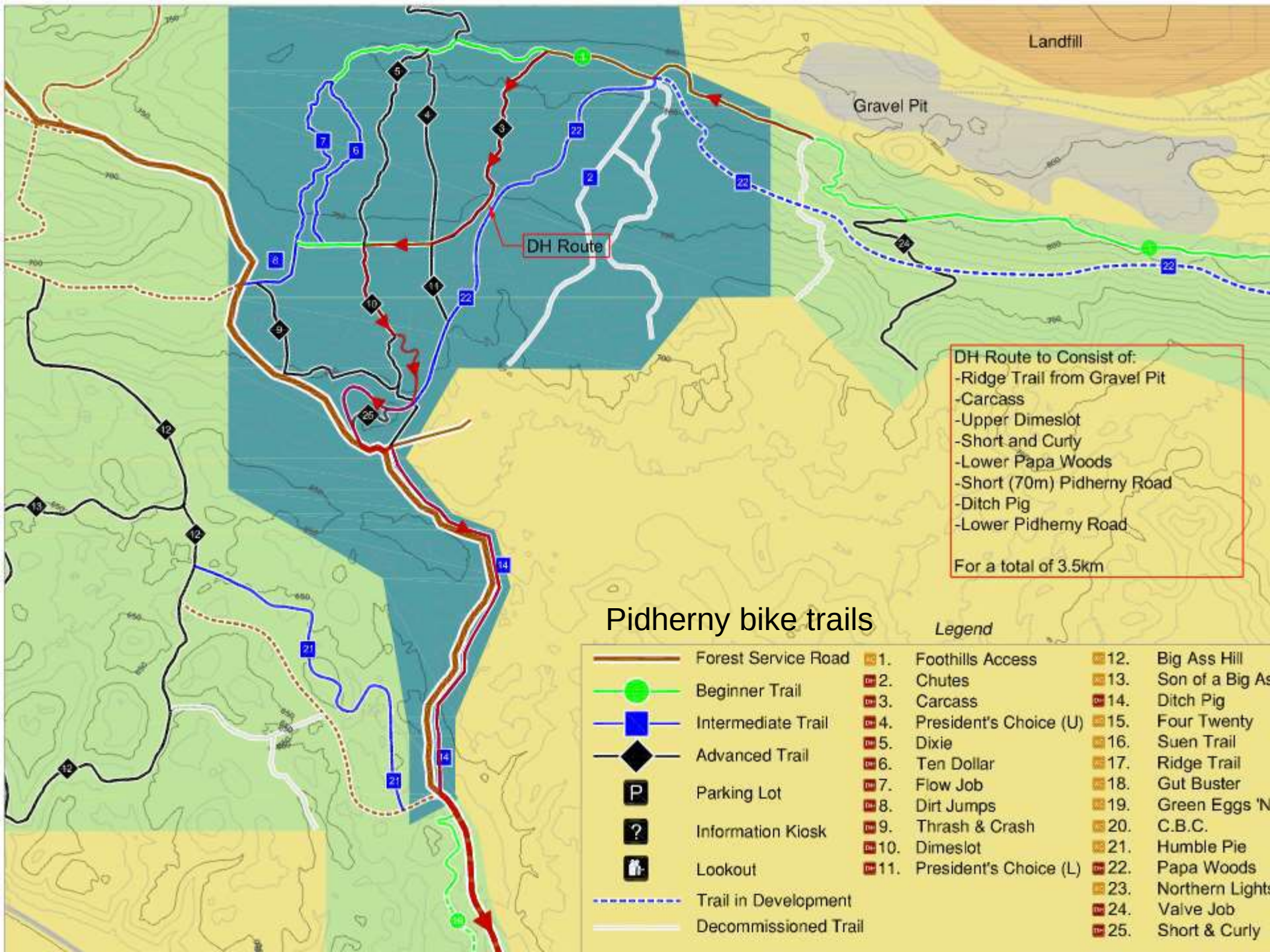
Global Positioning Systems (GPS)

Trails: the achilles heel of mapping from the air / satellites
- Even UAVs and LiDAR

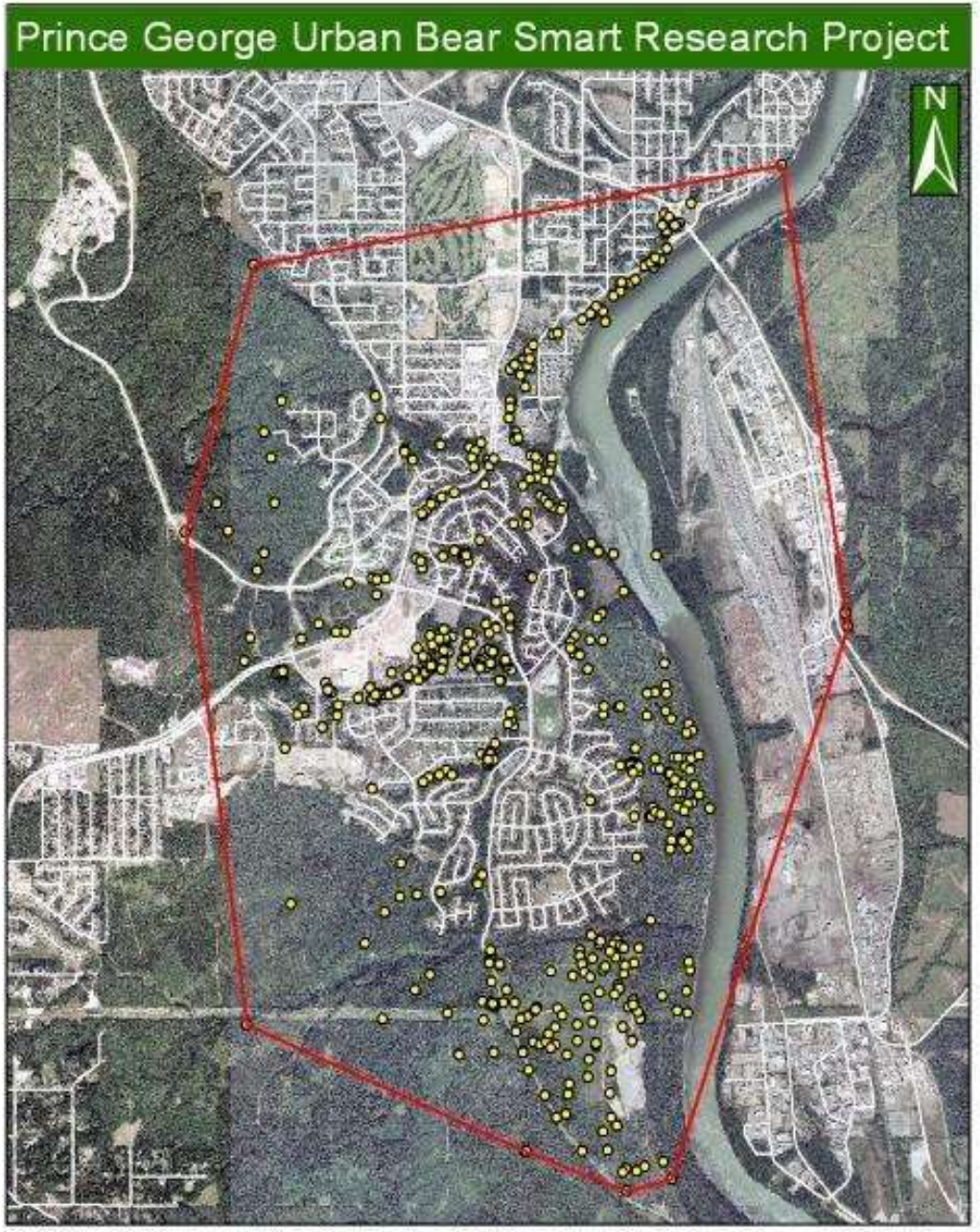

Landfill
Gravel Pit
DH Route
DH Route to Consist of:
-Ridge Trail from Gravel Pit
-Carcass
-Upper Dimeslot
-Short and Curly
-Lower Papa Woods
-Short (70m) Pidherny Road
-Ditch Pig
-Lower Pidherny Road
For a total of 3.5km
Pidherny bike trails
Legend
Forest Service Road
Beginner Trail
Intermediate Trail
Advanced Trail
Parking Lot
Information Kiosk
Lookout
Trail in Development
Decommissioned Trail
1. Foothills Access
2. Chutes
3. Carcass
4. President's Choice (U)
5. Dixie
6. Ten Dollar
7. Flow Job
8. Dirt Jumps
9. Thrash & Crash
10. Dimeslot
11. President's Choice (L)
12. Big Ass Hill
13. Son of a Big As
14. Ditch Pig
15. Four Twenty
16. Suen Trail
17. Ridge Trail
18. Gut Buster
19. Green Eggs 'N
20. C.B.C.
21. Humble Pie
22. Papa Woods
23. Northern Lights
24. Valve Job
25. Short & Curly

GPS applications – polygons

Northern Bear Awareness Society

GPS wildlife collars - point collection

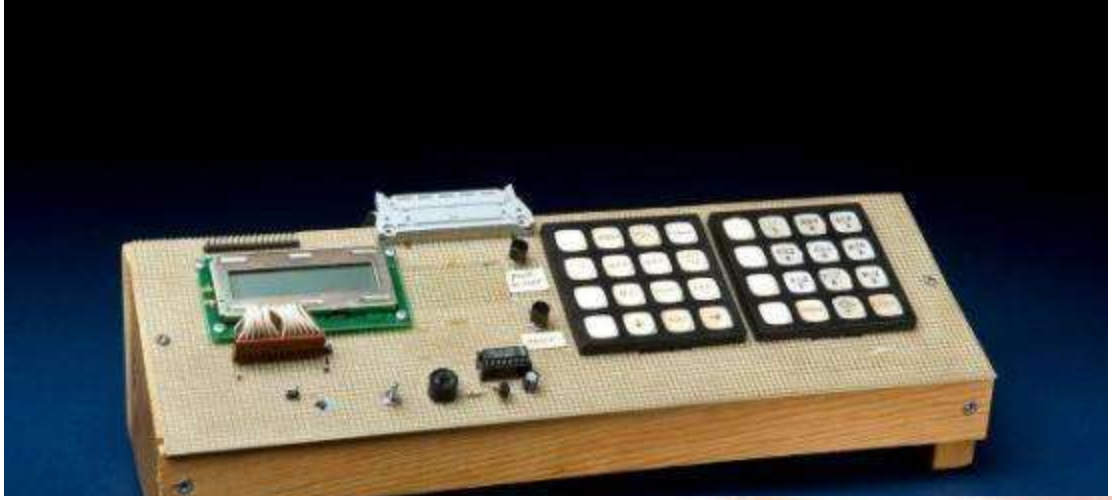
- monitor movements to minimise conflicts between predictable bears and unpredictable humans



Global Positioning Systems – GPS

- How much do we need to know ?
- Turn it on, it gives your position ?
- You move, the position changes
- You don’t move, the position changes - what ?
- Download the data for mapping e.g. .gpx

GPS in the 1980s



What is GPS ?

The **Global Positioning System** (**GPS**) is a satellite system that provides locations anywhere on Earth where there is a clear line of sight to four or more GPS satellites. (wikipedia)

Satellites launched 1978->
System 'first operational' 1989

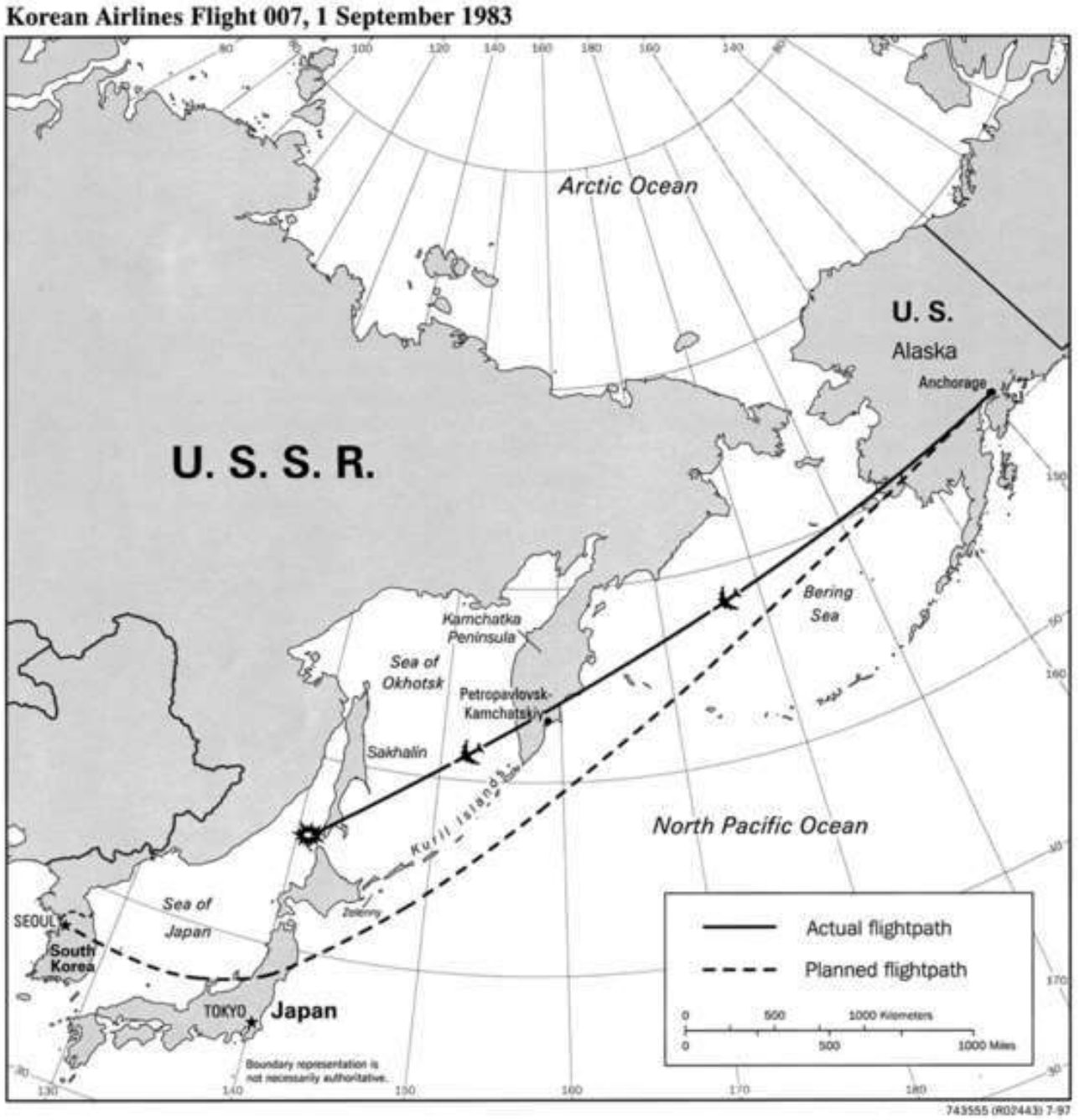
list of satellites:
http://en.wikipedia.org/wiki/List_of_GPS_satellites

Do we need to know any more ?
https://slideplayer.com/slide/5667079

Satellites launched 1978->

1983 President Reagan insists civilians must have GPS technology when it is ready

Initially designed to pinpoint locations and also reduce civilian casualties



The **Global Positioning System** (GPS)

Global Navigation Satellite System (GNSS)

… a satellite-based navigation system consisting of a network of 24 orbiting satellites that transmit radio signals to GPS receivers (fully operational 1995)

The system consist of 3 'segments':

- Space segment
- Control segment
- User segment

1. Space segment: Satellite Constellation

GPS is 'just' the USA system (1978->)

Russia has GLONASS (1982->)
"Global Navigation Satellite Systems"
Operational by 1995, Restored in 2011

Europe has Galileo (2011->)

24 satellites at 20,000 km altitude,
at 55° angle to equator

(Galileo is at 56 degrees, Glonass is at 65 degrees)

2. Control segment: ground stations

These 5 stations monitor the GPS satellites, check their operational health and exact position in space. The master station transmits corrections for the satellite's orbit and clock offsets back to the satellites

Ascension Island

Diego Garcia

In 1971, 2000 inhabitants were forcibly removed from **Diego Garcia** to Mauritius to enable a US military base; 1000 pet dogs gassed in a warehouse

Islanders were later denied compensation in 2003 by the Blair government

http://www.guardian.co.uk/politics/2004/oct/02/foreignpolicy.comment
https://www.bbc.com/news/uk-48426031 ..... **descendants feel like 'lost nation'**

3. User segment: GPS receivers/ antennas
with relative accuracy

Handheld recreation units Smartphones	5-15 m
Resource grade units	1-5 m
Survey grade units	1 cm

Pre-GPS surveying: identification of point locations
Survey triangulation (3 points/angles)

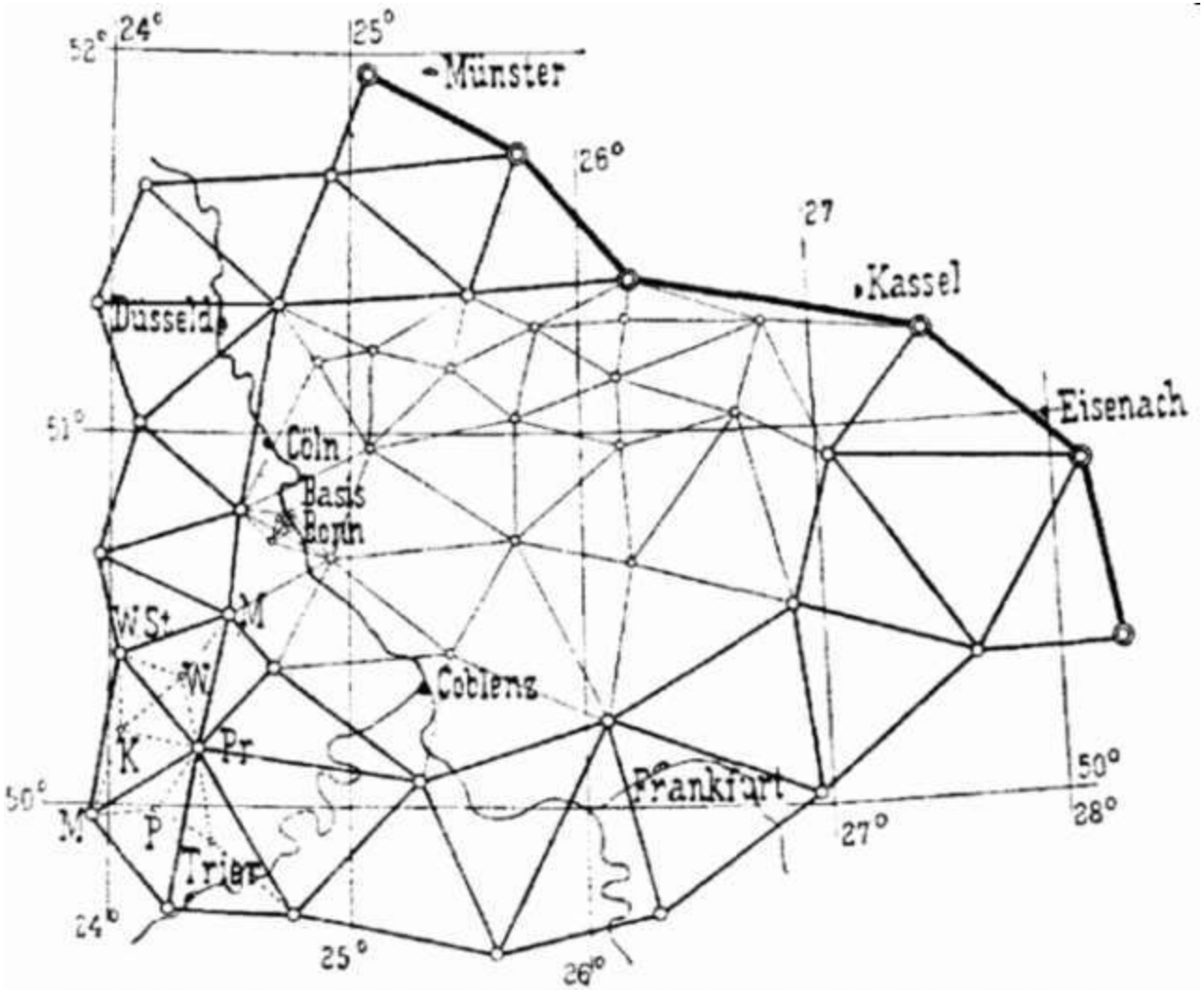
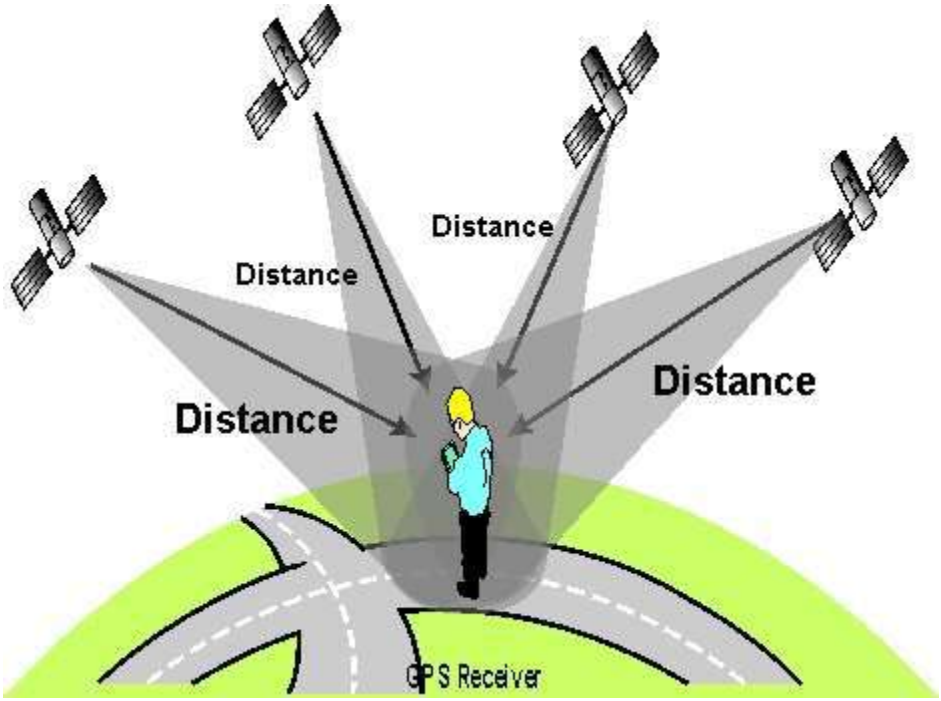


Fig. 4. Die rheinisch-hessische Kette und das niederrheinische Dreiecksnetz.

GPS Trilateration



Distance = Time x Speed

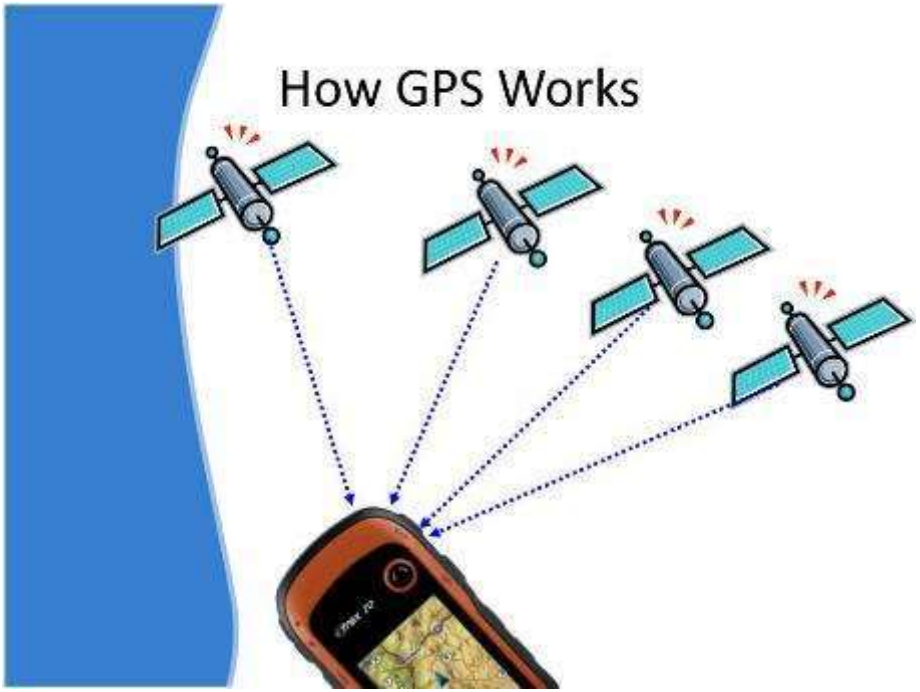
(Speed = 300,000 km/sec)

Code is transmitted many thousand times a second and includes

- Time
- Which satellite it is
- XYZ coordinates (ephemeris)

Atomic clocks measure time in seconds to 10 decimal places

Trilateration



1. Satellite sends out signal/code
   e.g. at midnight (with date stamp)

2. GPS units receives code at time
   plus travel time (decimal seconds)

3. The delay or lag when the GPS
   receives it is the signal's travel time.

4. GPS unit multiplies the time by the
speed of light to determine how far the signal travelled
= how far you are from that point in space
   (Speed = 300,000 km/sec)

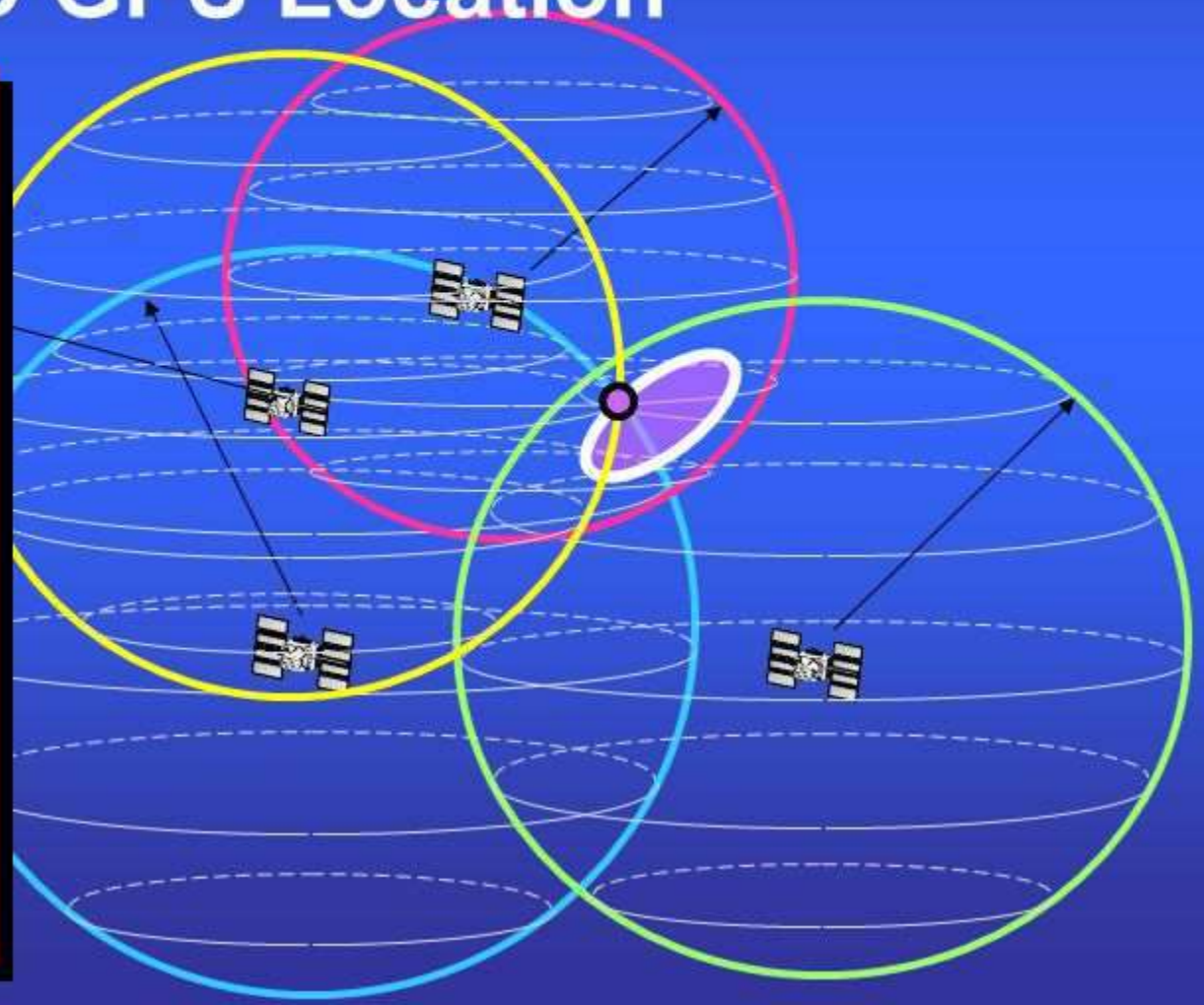
5. Software combines the > 4 readings to generate a ground location (with some degree of error)

Solves for x, y, z and 'time' – uncertainty of ground clock

Minimum # of Satellites Required -Trilateration

4 satellites – one point 3D GPS Location

Note: with 3 satellites, one point is on the earth's surface and one is nowhere near. However, we still need the 4th satellite because receiver clocks are inaccurate.

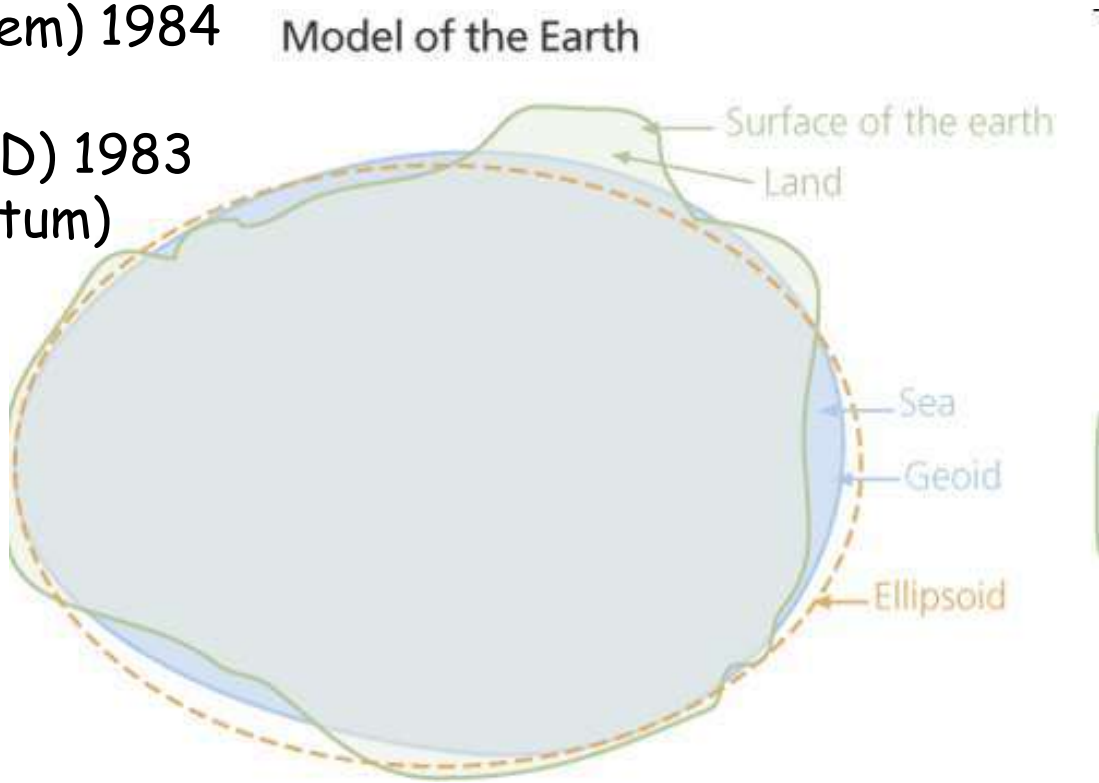


Location coordinates can be recorded by the GPS as:

- Latitude / Longitude – D/M/S or decimal degrees OR
- UTM eastings and northings, with zone (in metres)

And relative to the most current measured shape of the earth (ellipsoid):

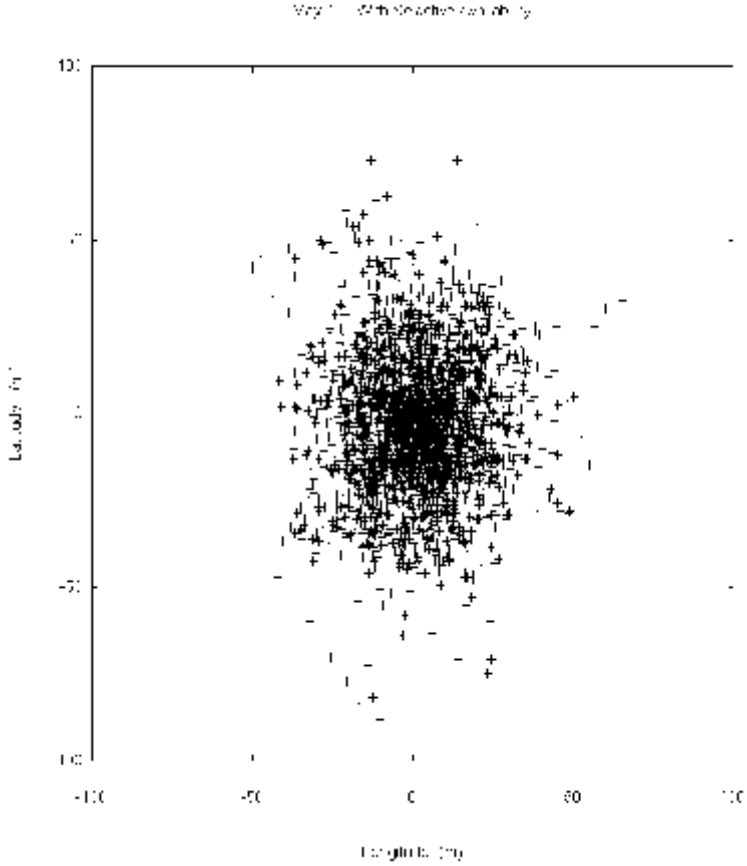
- WGS (World Geodetic System) 1984
- North American Datum (NAD) 1983
  (local mapping reference datum)



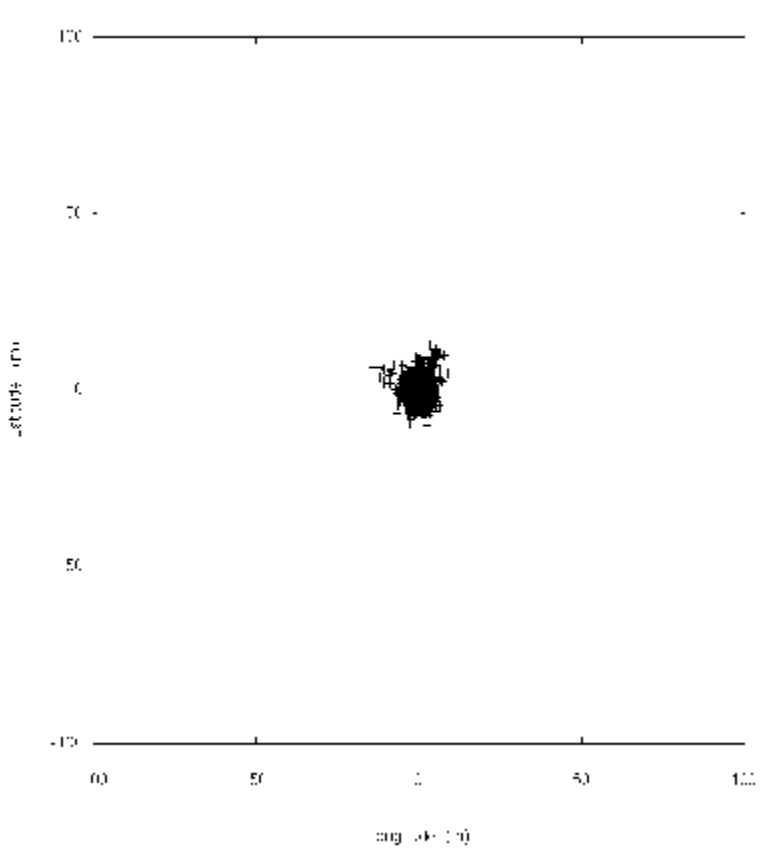
GPS terms: 1. Selective Availability (SA)

- **Random error, added to GPS signals before 2000**
- .. up to 100 metres error by scrambling last 3 decimals of time signal
- Turned off May 1, 2000 at midnight; No intent to ever use it again
- e.g. Time = 3.1234567890 = 2.1234567000

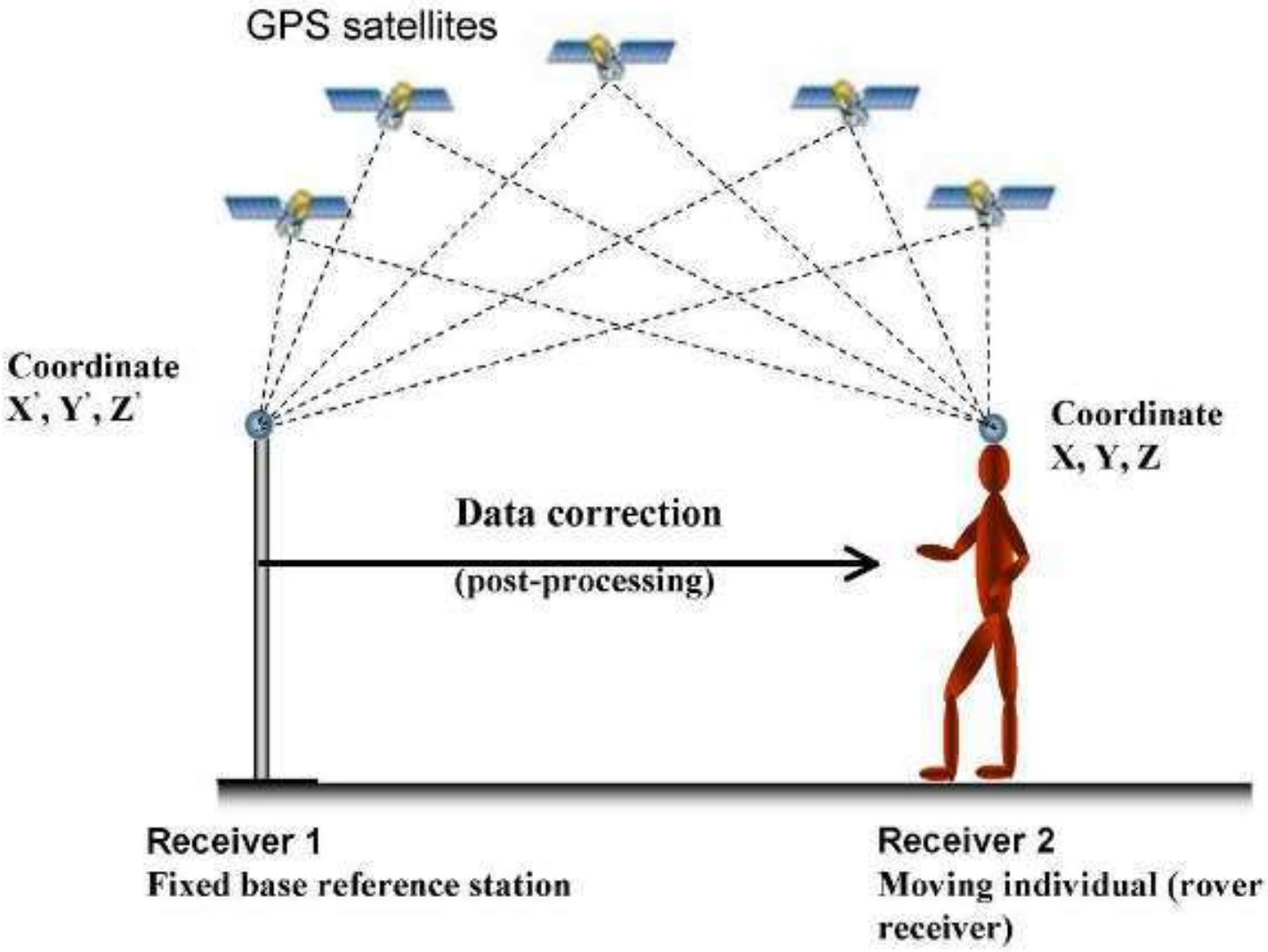
May 1, 2000 – Selective Availability on



May 3, 2000 – Selective Availability Off



2. Differential Correction (DGPS) –industry solved SA problem

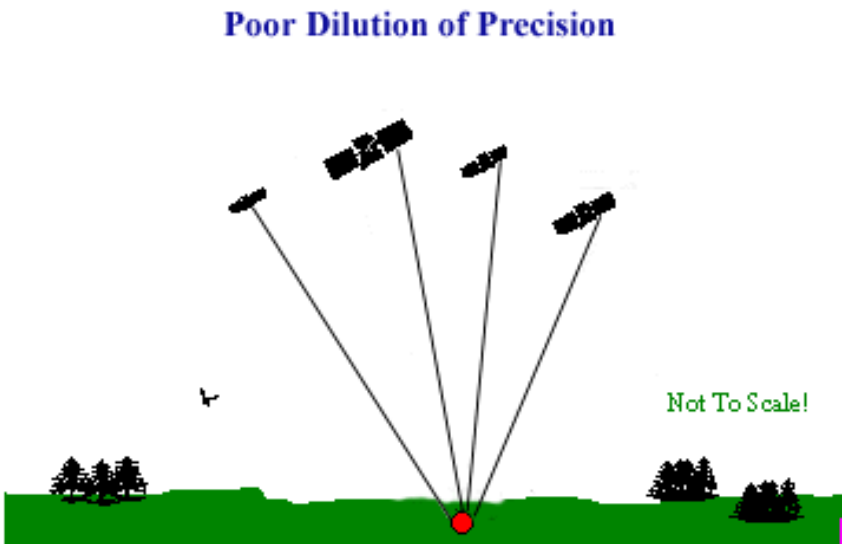


Base station, Coast Mountains, Mt. Waddington – real-time DGPS

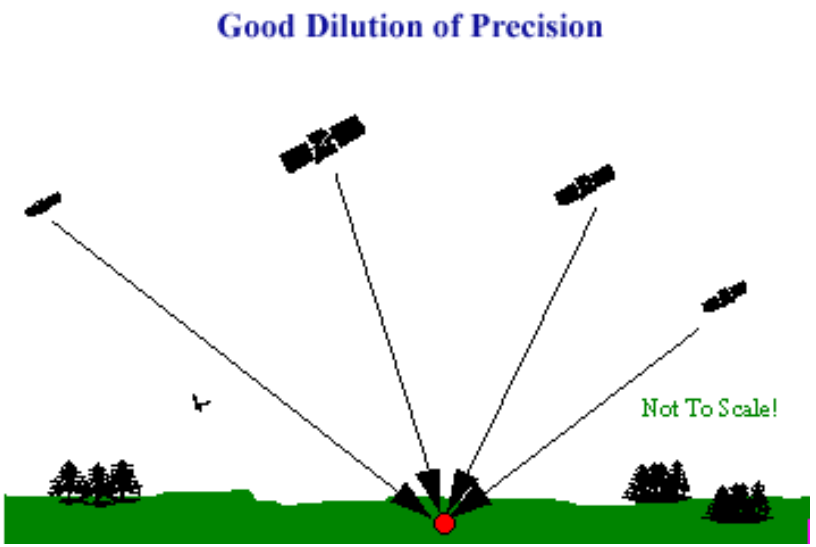
3. (Percent) Dilution of Precision

- **PDOP is an indicator of the quality of the geometry of the satellites**
- Well spread out, and not too low in the sky

BC standard: PDOP < 8.0 acceptable **PDOP < 4.0 : excellent**

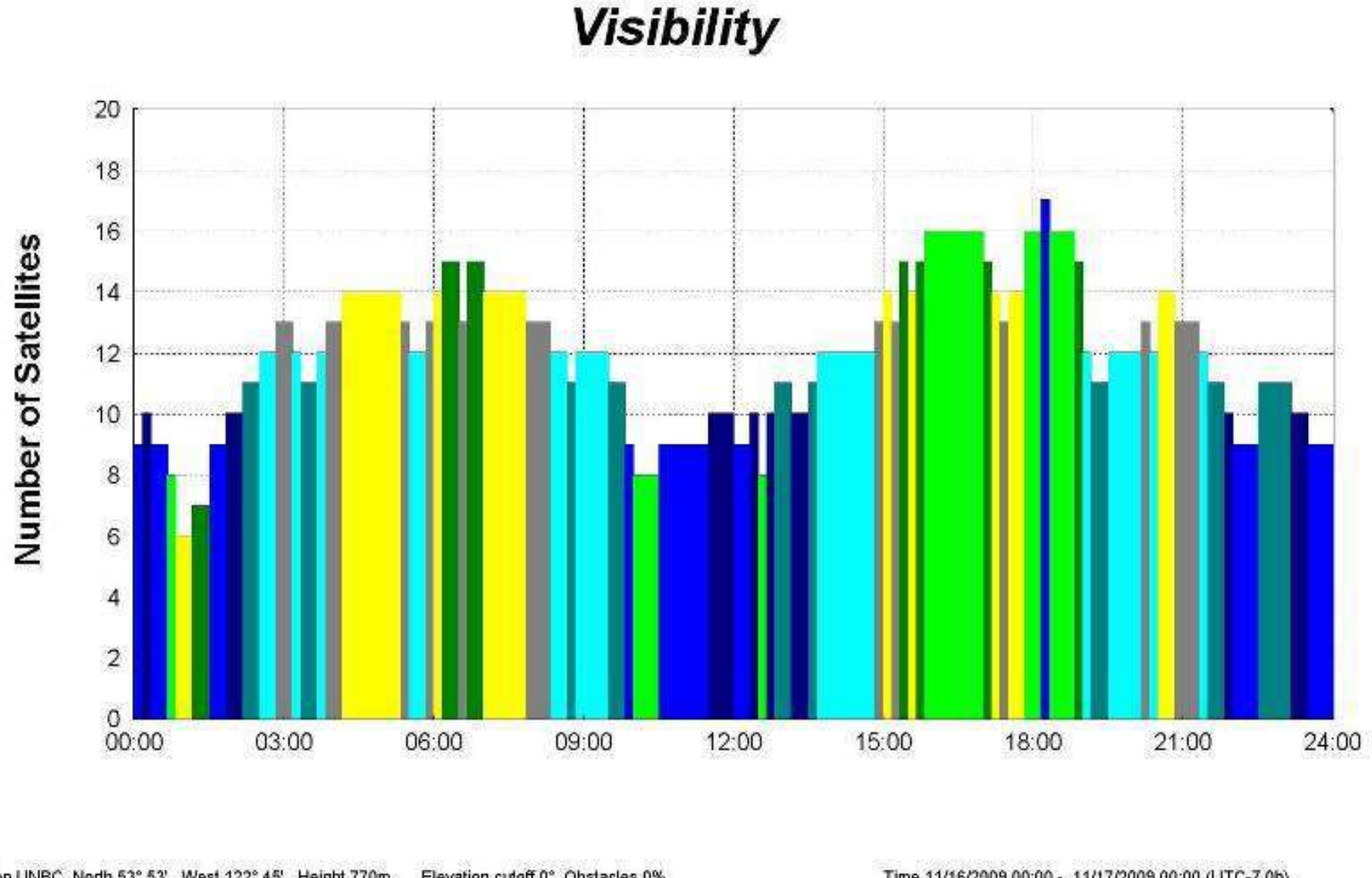


High DOP (poor)



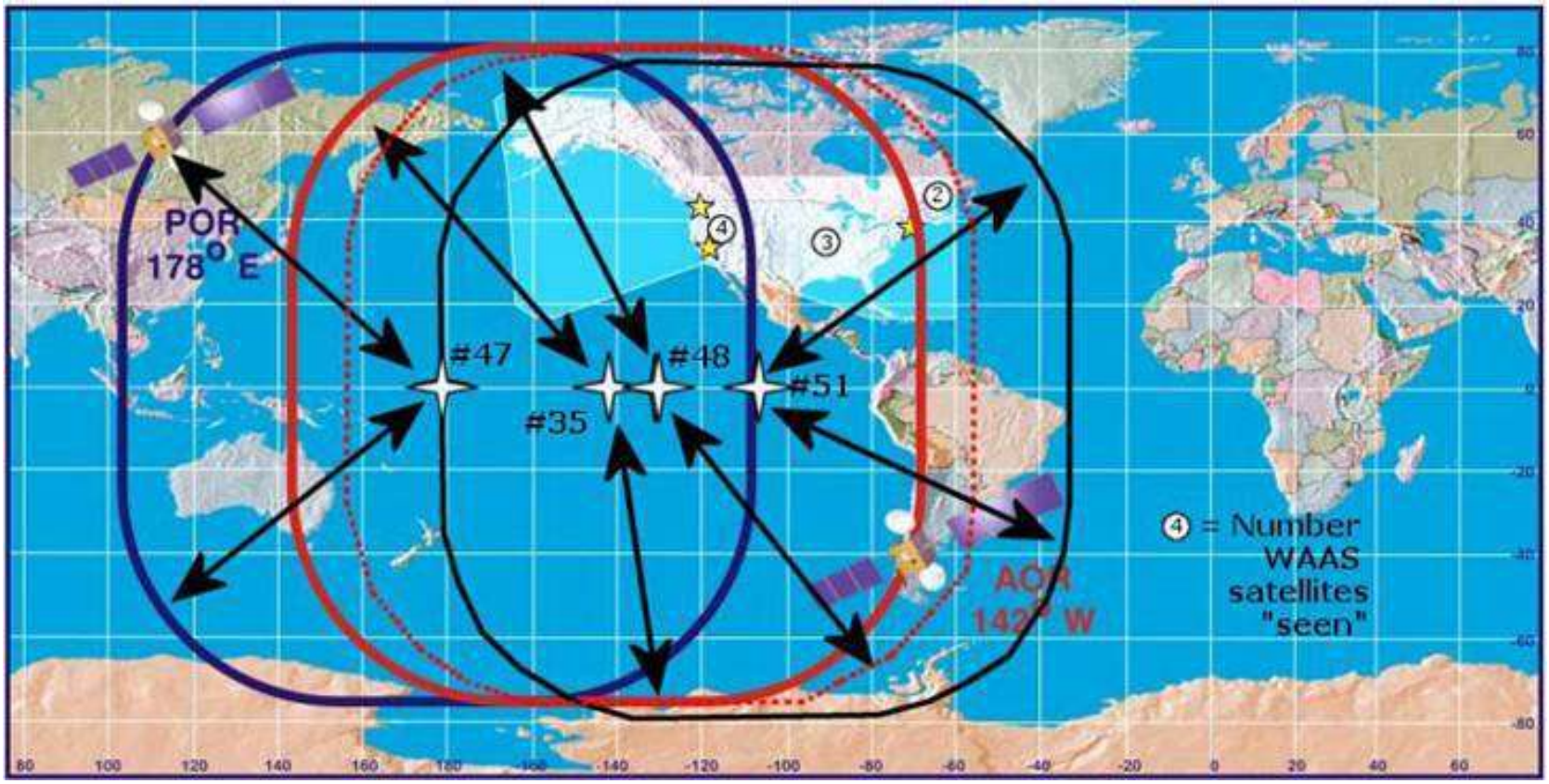
Low DOP (good)

of satellites (affects PDOP)

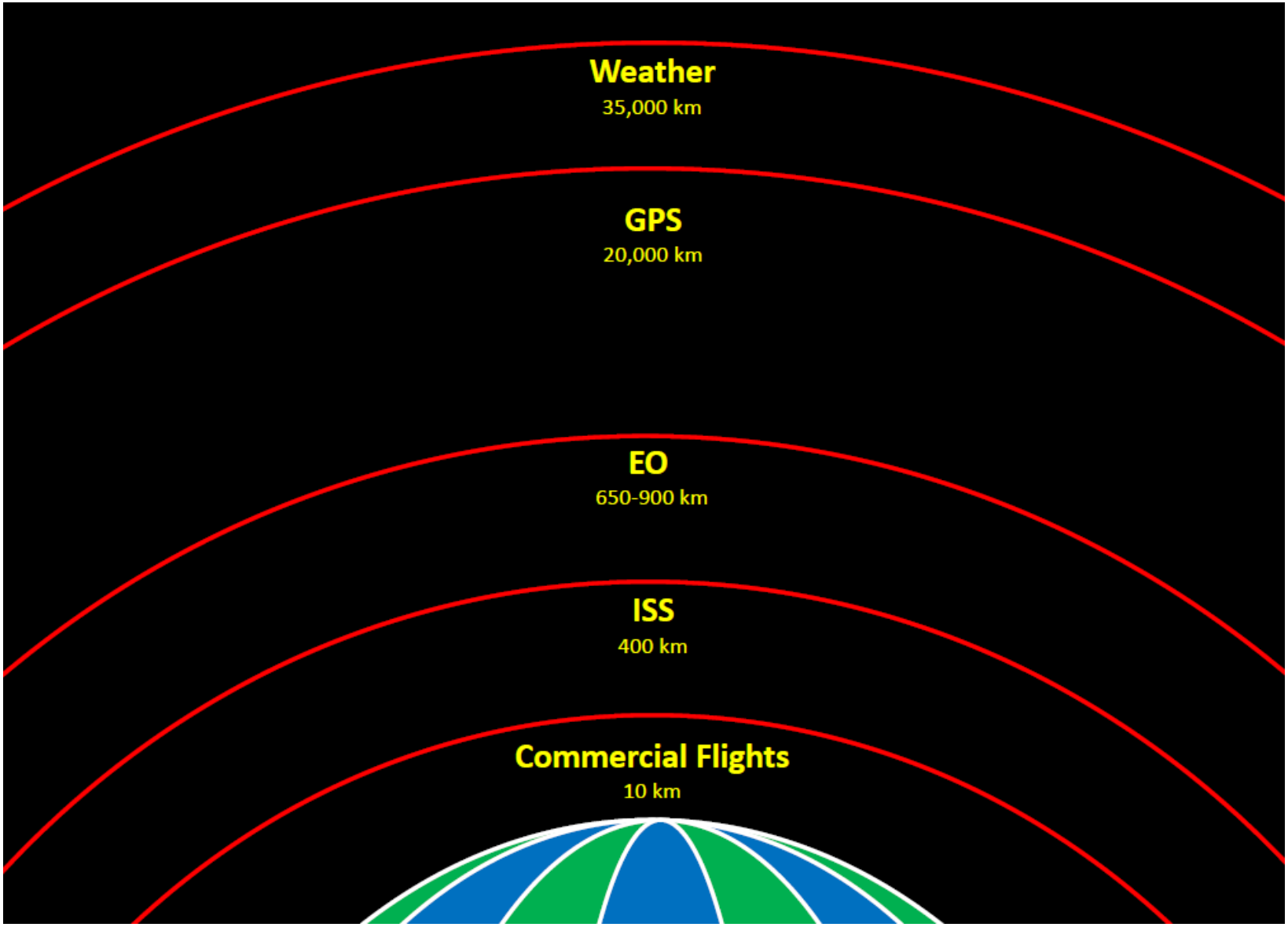


WAAS (Wide Area Augmentation System) Geostationary Satellites (since 2003)

POR	#47	3F3	Pacific Ocean at 178.0°E@
AOR-W	#35	3F4	Pacific Ocean at 142.0°W@
PanAm	#48	Galaxy 15	Pacific Ocean at 133.0°W*
Anik	#51	F1R	Pacific Ocean at 107.3°W*



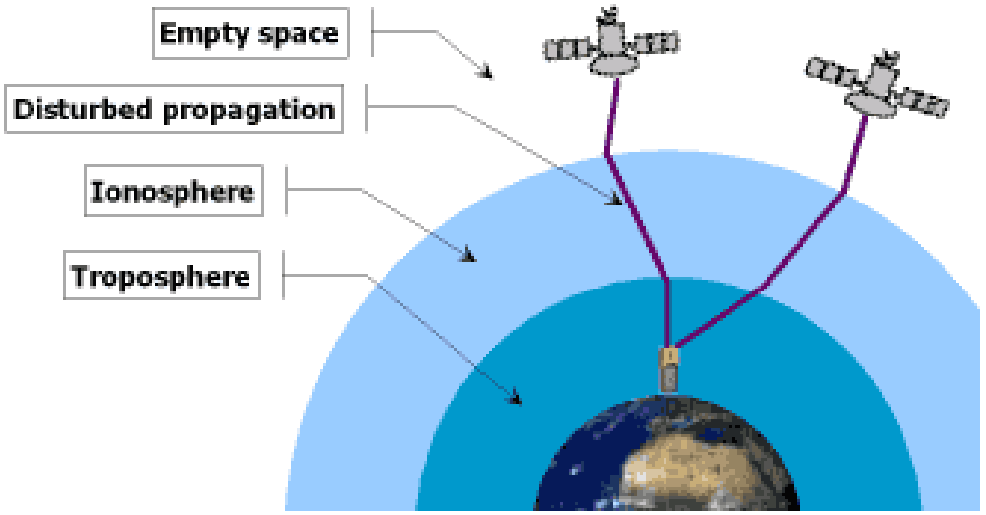
Earth from Space: Earth Observation (EO) satellites



What are the remaining sources of error?
(after SA removed and good PDOP)

Potential Error

Ionosphere	4.0 metres
Clock	2.1 m
Ephemeris	2.1 m
Troposphere	0.7 m
Receiver	0.5 m
Multipath	1.0 m
Total	**10.4 m**



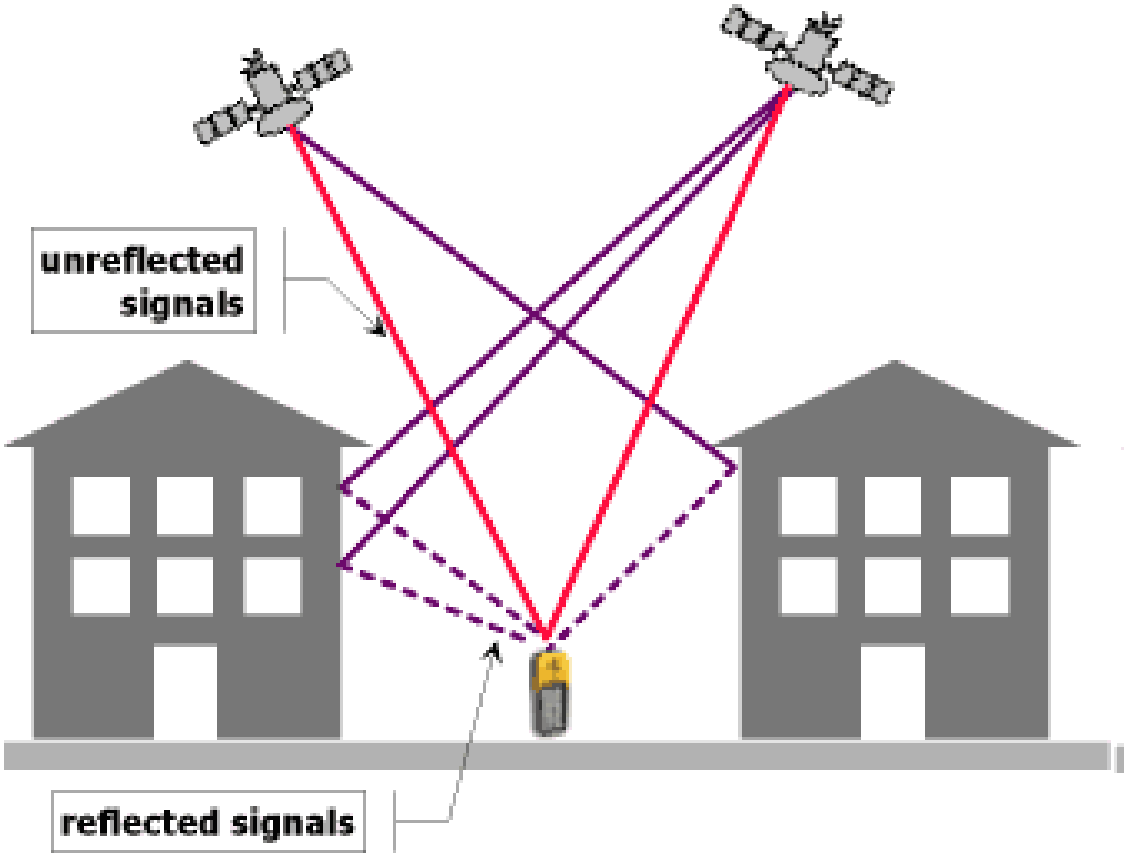
This is why your reading can change even when you don't move

We use DGPS to help remove these errors …

Uncorrected GPS ~10m
Corrected (DGPS) ~1m

You can reduce error by taking the average of many readings e.g. at trail junctions

Multipath: GPS is line of sight



In the way: e.g. buildings, mountains, solid canopy ..

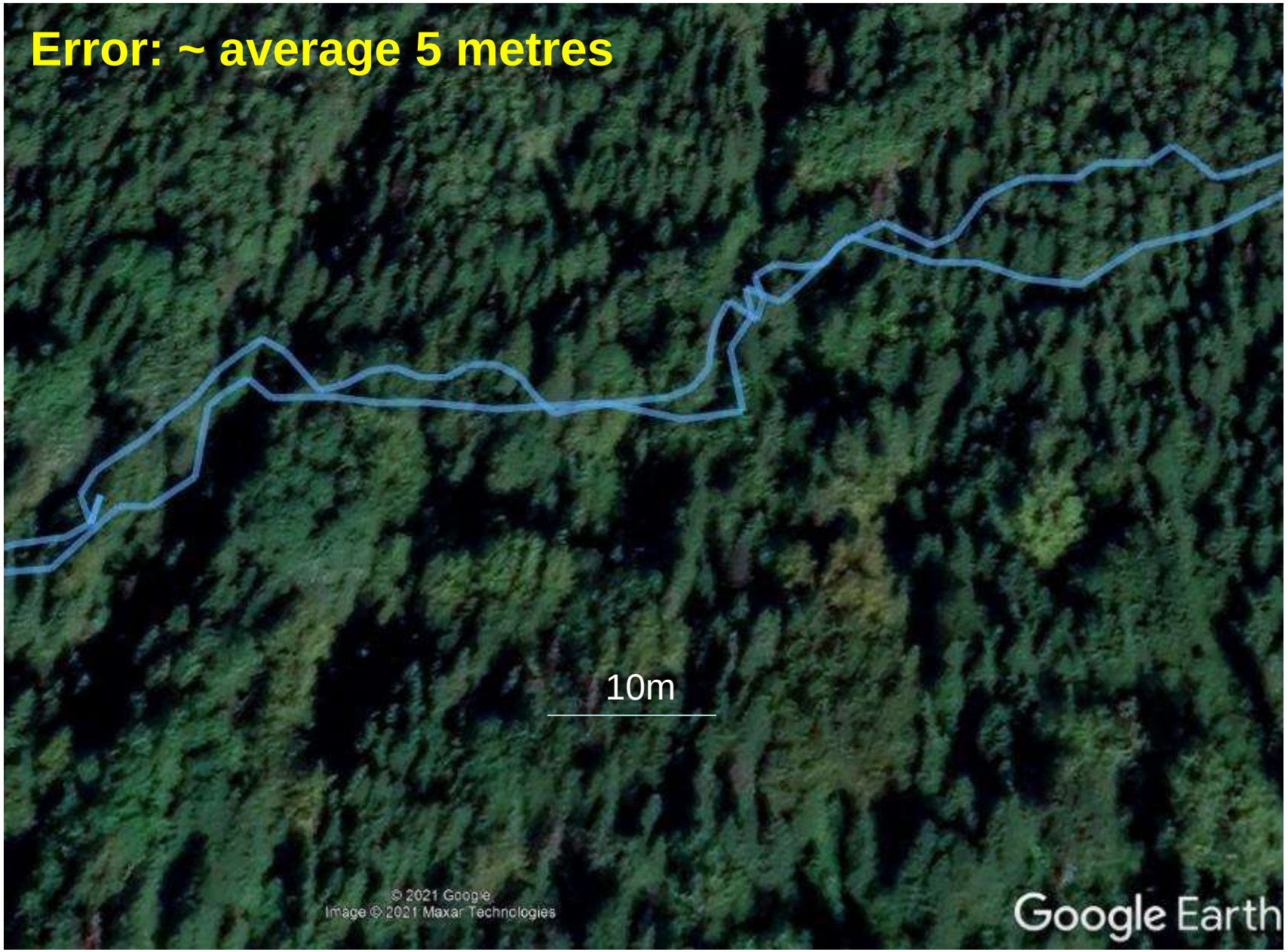
High latitude, E-W valleys, e.g. Norway

the valley sides may block good GPS reception …

Environmental Factors ?

- Generally, GPS is unaffected by weather
- Heavy rain can weaken the signal
- Wet foliage deflects more than dry foliage
- General Humidity and Temperature – no effect
- Wind may have positive effect under forest canopy

GPS track on Cranbrook Hill – out and back same trail, iPhone



Data quality: Spatial generalization, accuracy and precision: GPS and GIS

Trailhead

Johnston Canyon Resort, 17.5 km (11 mi) northwest along the Bow Valley Parkway from the Trans-Canada Hwy.

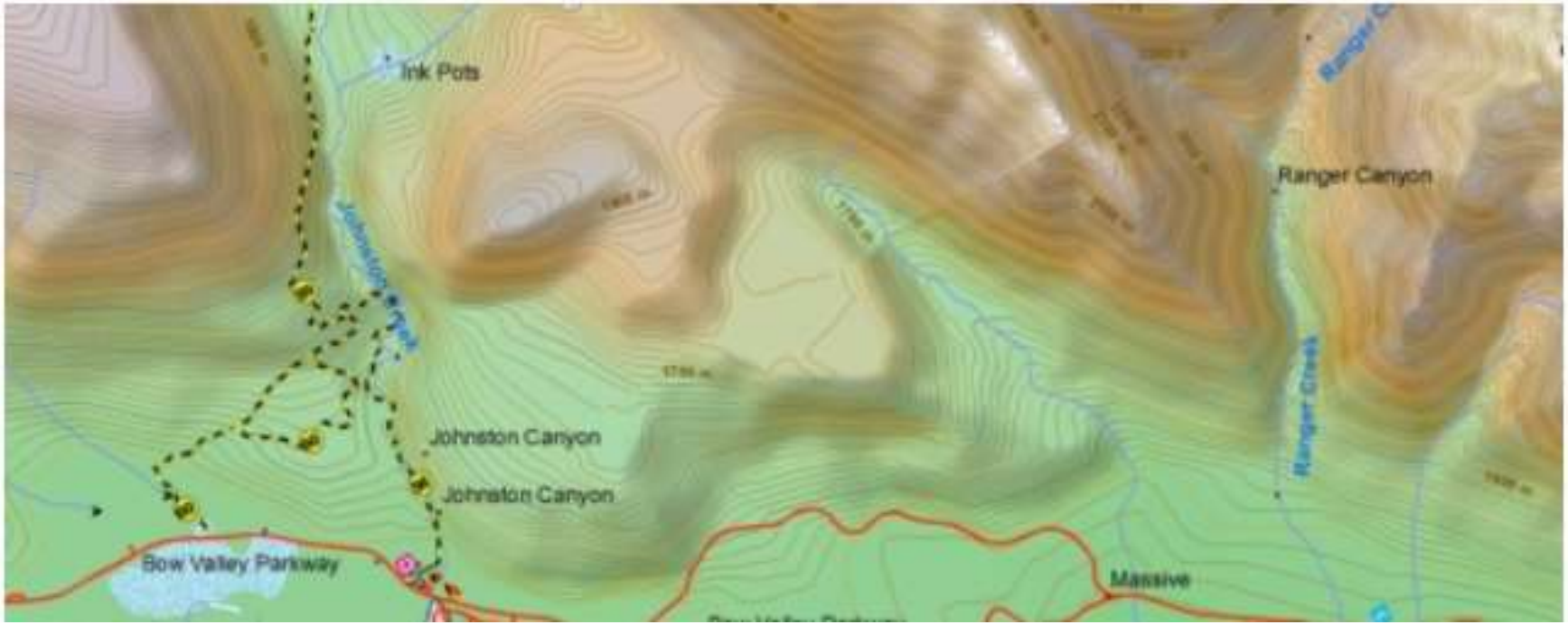
GPS Coordinates

Latitude: 51.245423072416 23

Longitude: -115.83992958068848

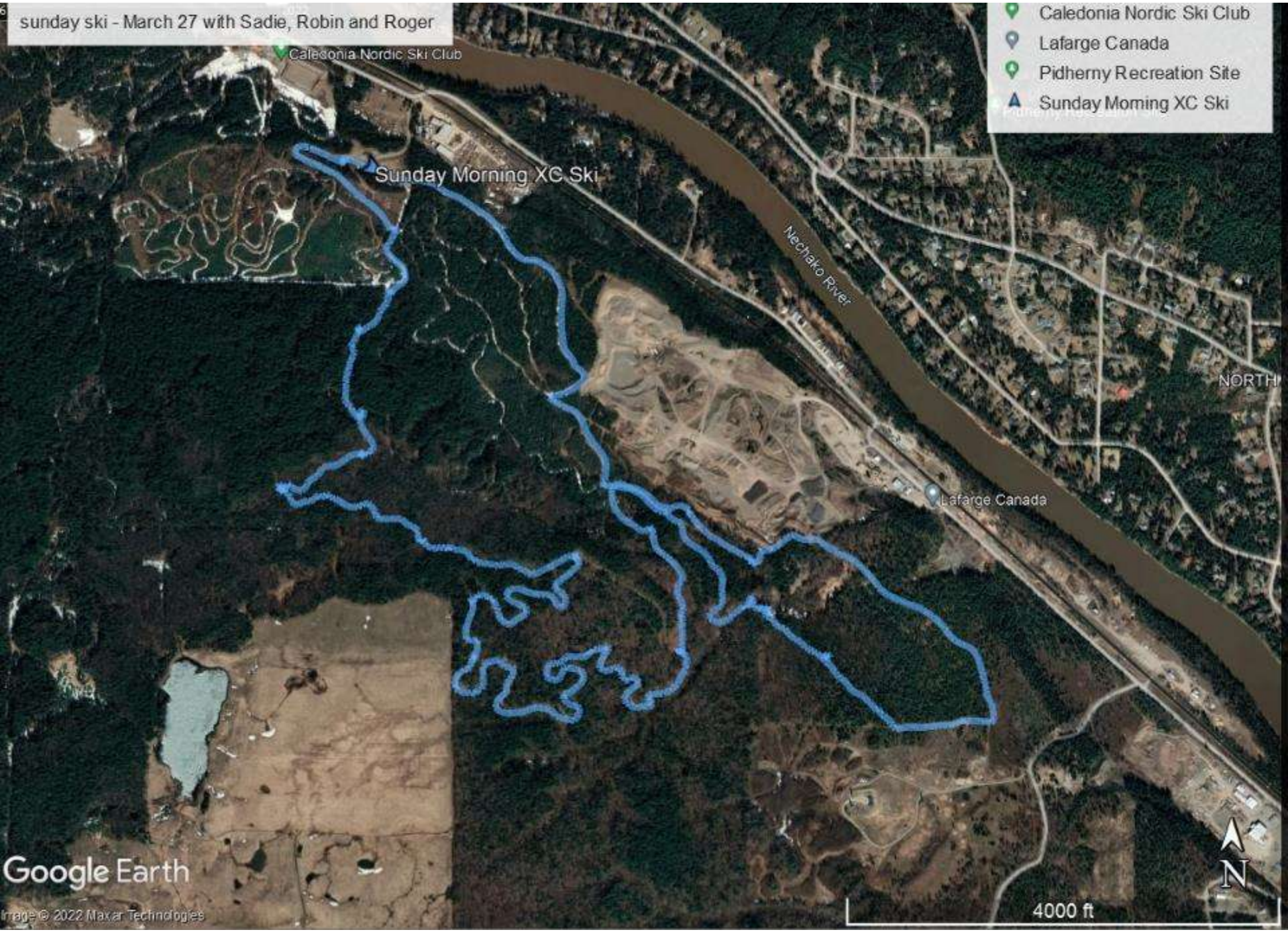
14 decimal places !
-too precise; NOT accurate
-not enough **generalization**
Last digit = millionths of a mm

Detailed Map



GPS directions along Cranbrook Hill Road

Mapped and updated by local users using GPS


sunday ski - March 27 with Sadie, Robin and Roger
Caledonia Nordic Ski Club
Lafarge Canada
Pidherny Recreation Site
Sunday Morning XC Ski
Sunday Morning XC Ski
Nechako River
NORTH
Lafarge Canada
Google Earth
Image © 2022 Maxar Technologies
N
4000 ft

iPhone v handheld GPS: advantages: better maps / software, larger screens, cheaper
Advantages of handheld GPS: longer battery life, higher precision, more rugged

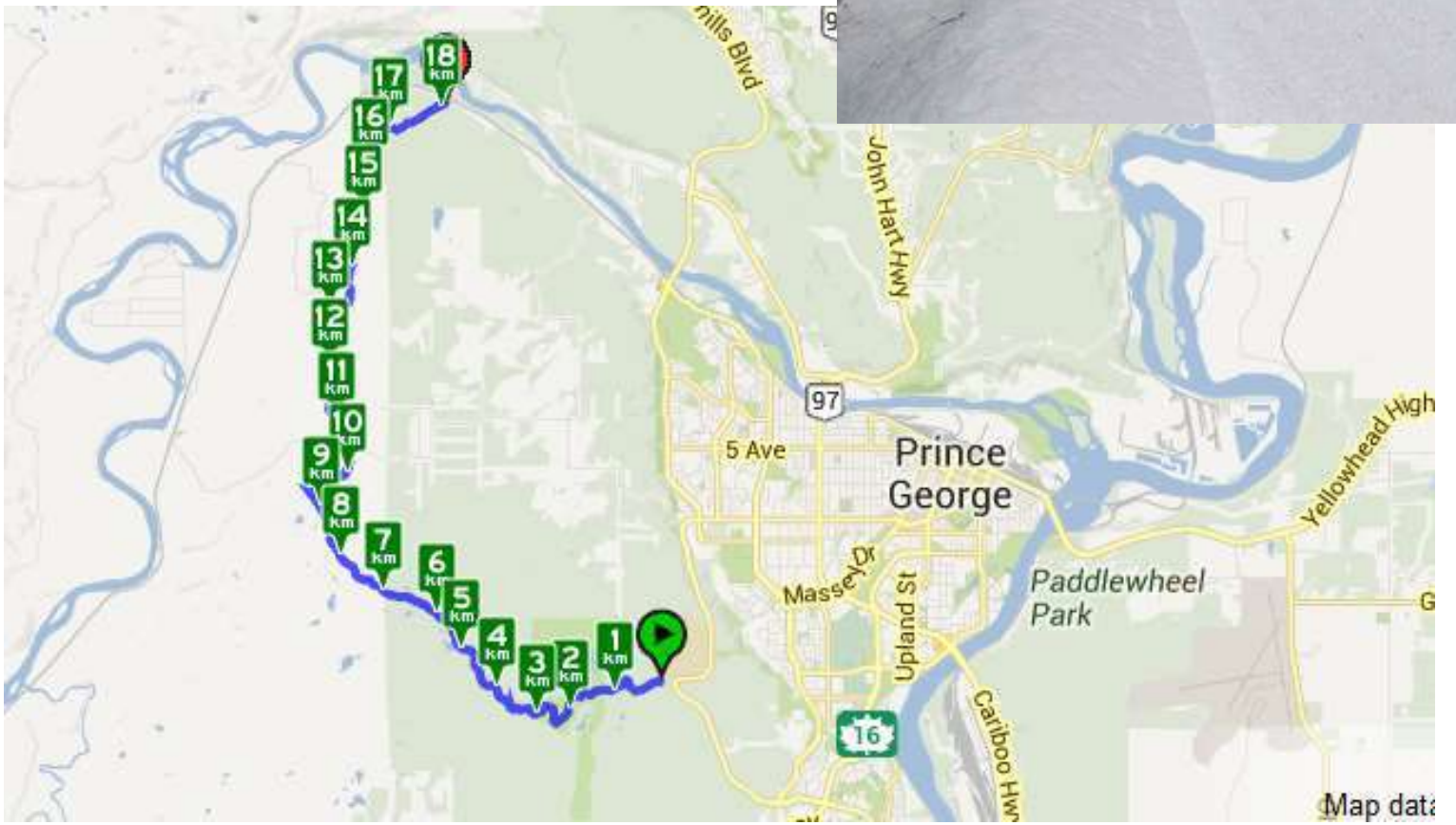
GPS data input:

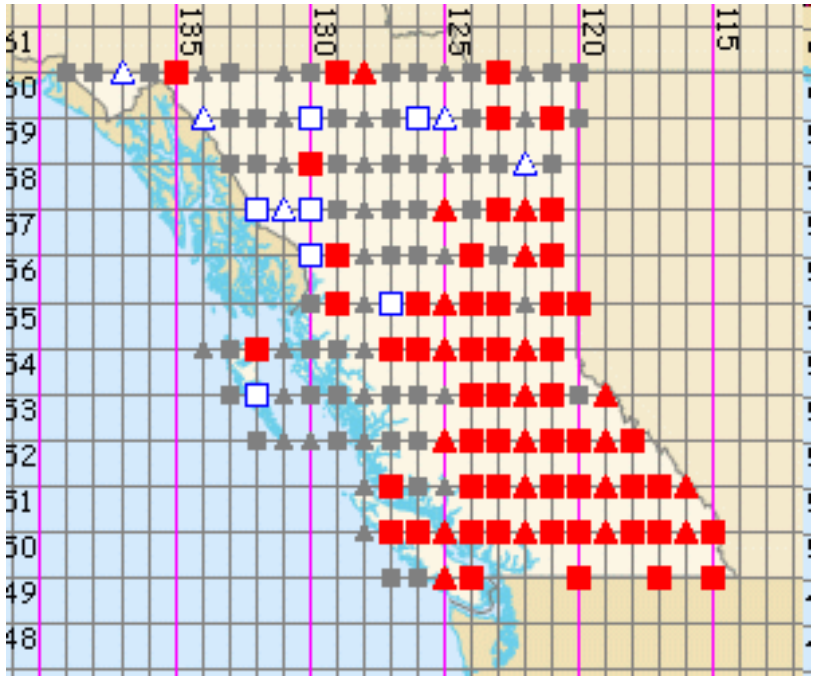
http://openstreetmap.org

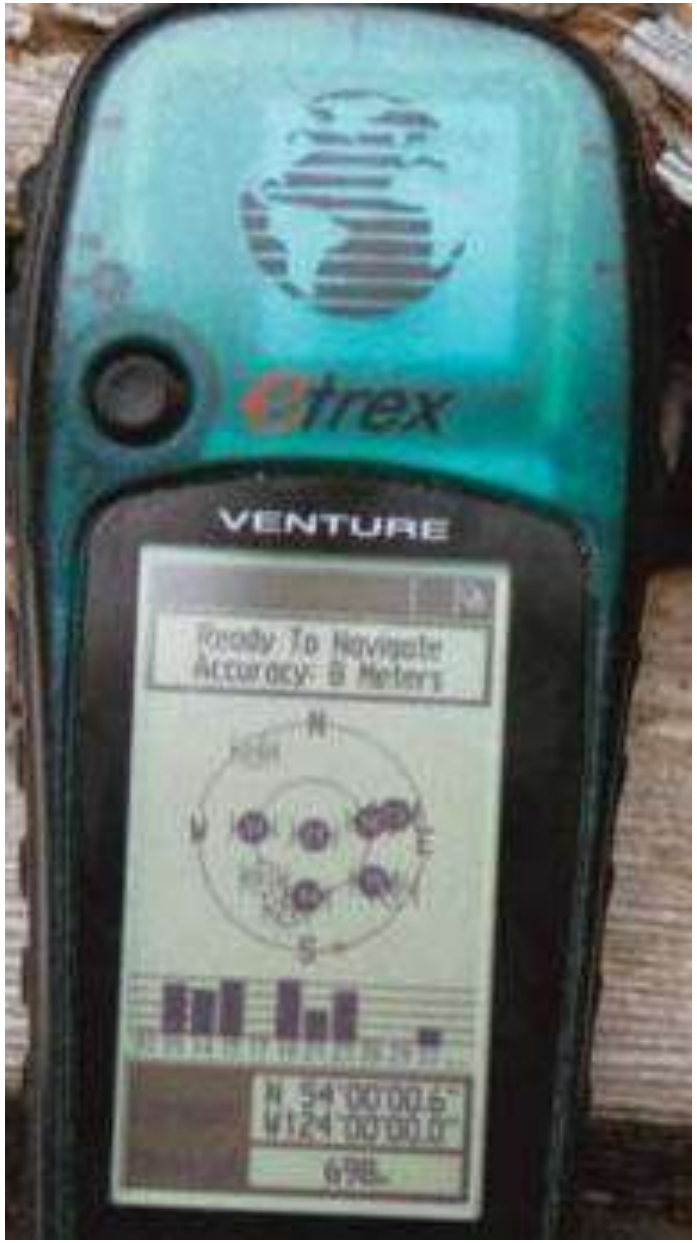
http://www.mapmyrun.com

https://www.geocaching.com

https://www.trailforks.com/trails/map/







Public mapping every degree intersection: http://confluence.org