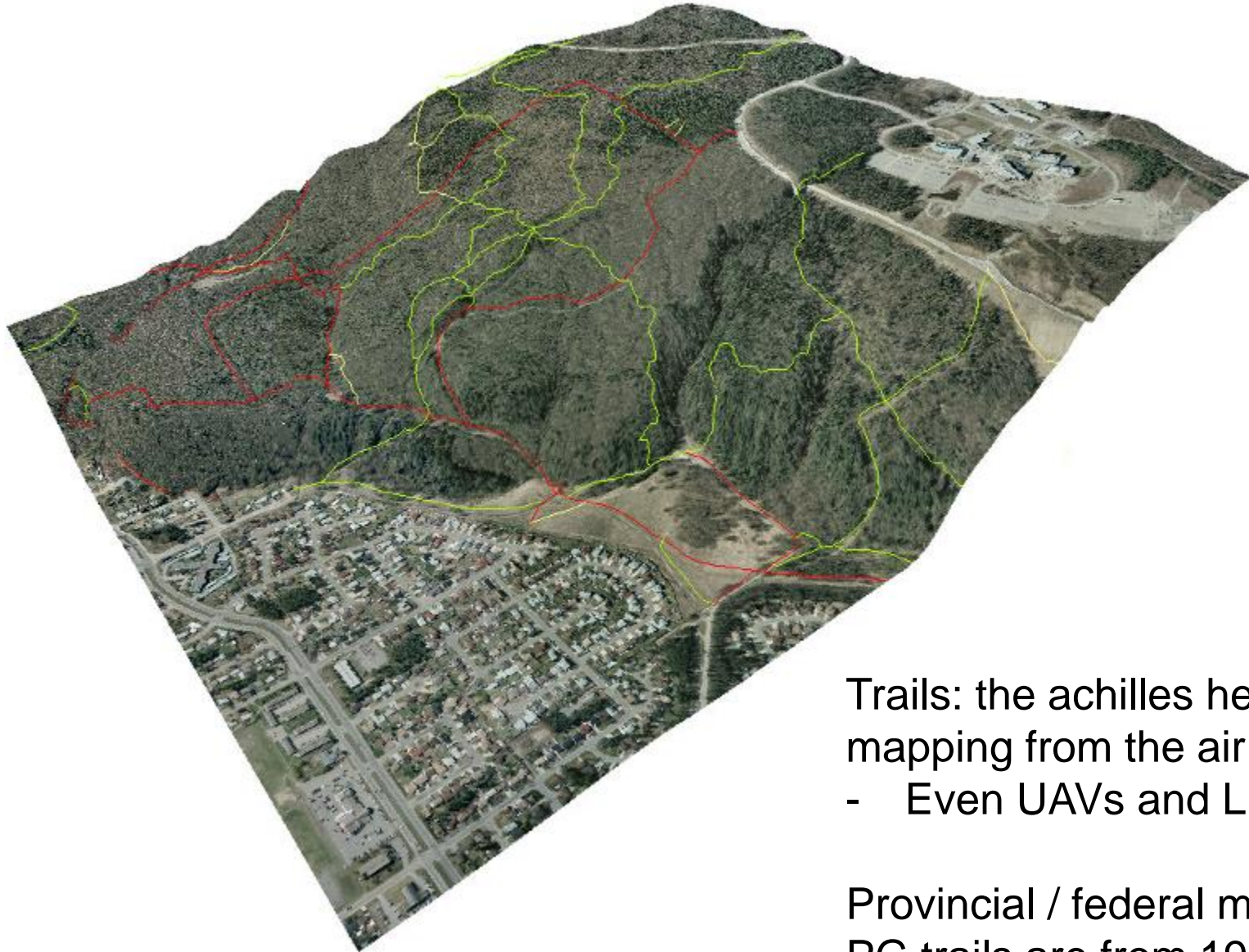


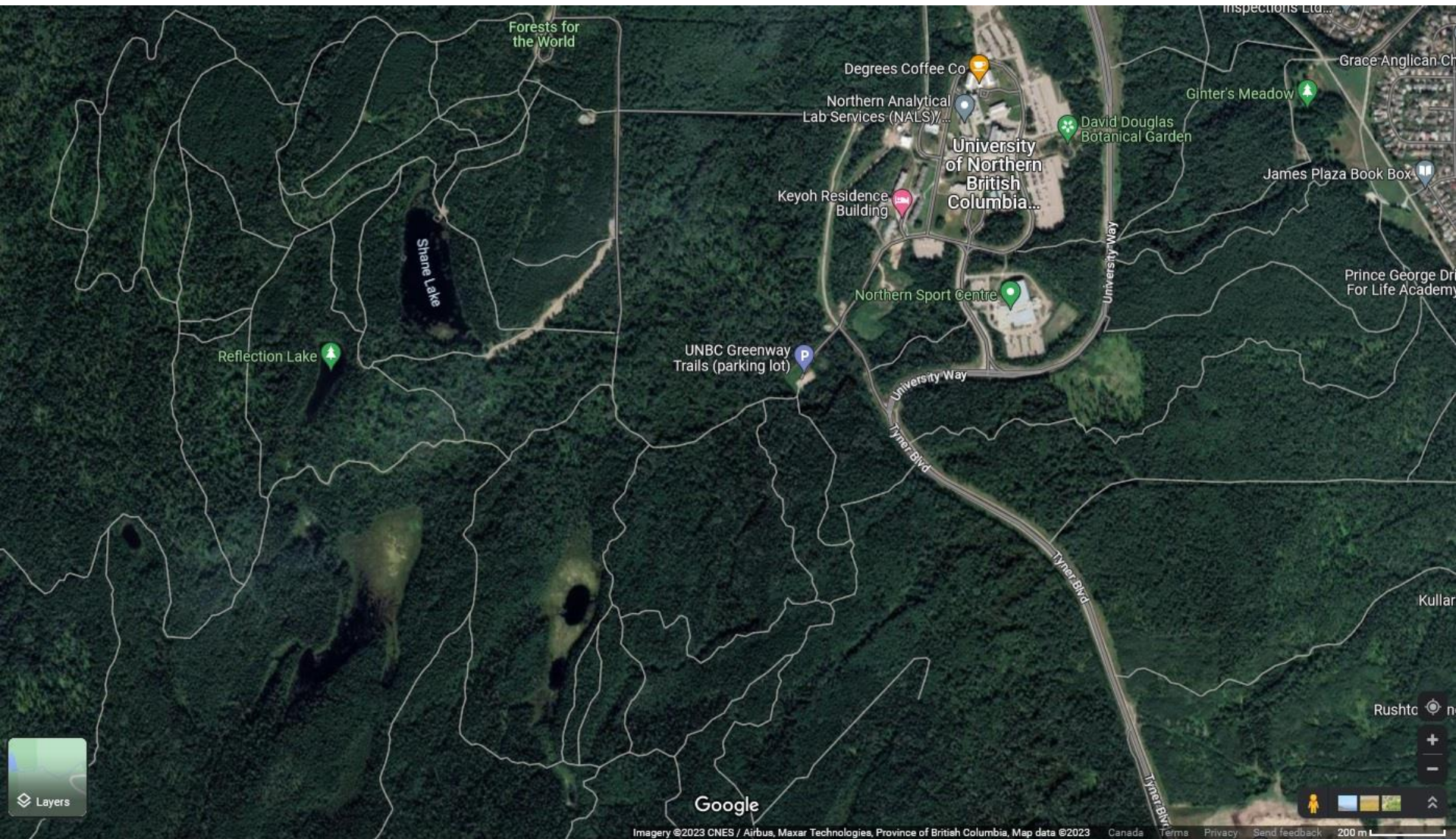
Global Positioning Systems (GPS)



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

Provincial / federal mapping:
PG trails are from 1982-85

Google maps – updated by citizens with GPS e.g. trails by bikers, general public
Mostly not surveyed, average accuracy; checked by Google for authenticity



Canada » British Columbia » Northern BC » Prince George

Prince George Mountain Biking Trails / city region

Overview

Areas

Trails

Routes

Status

Reports

Photos

Videos

Events

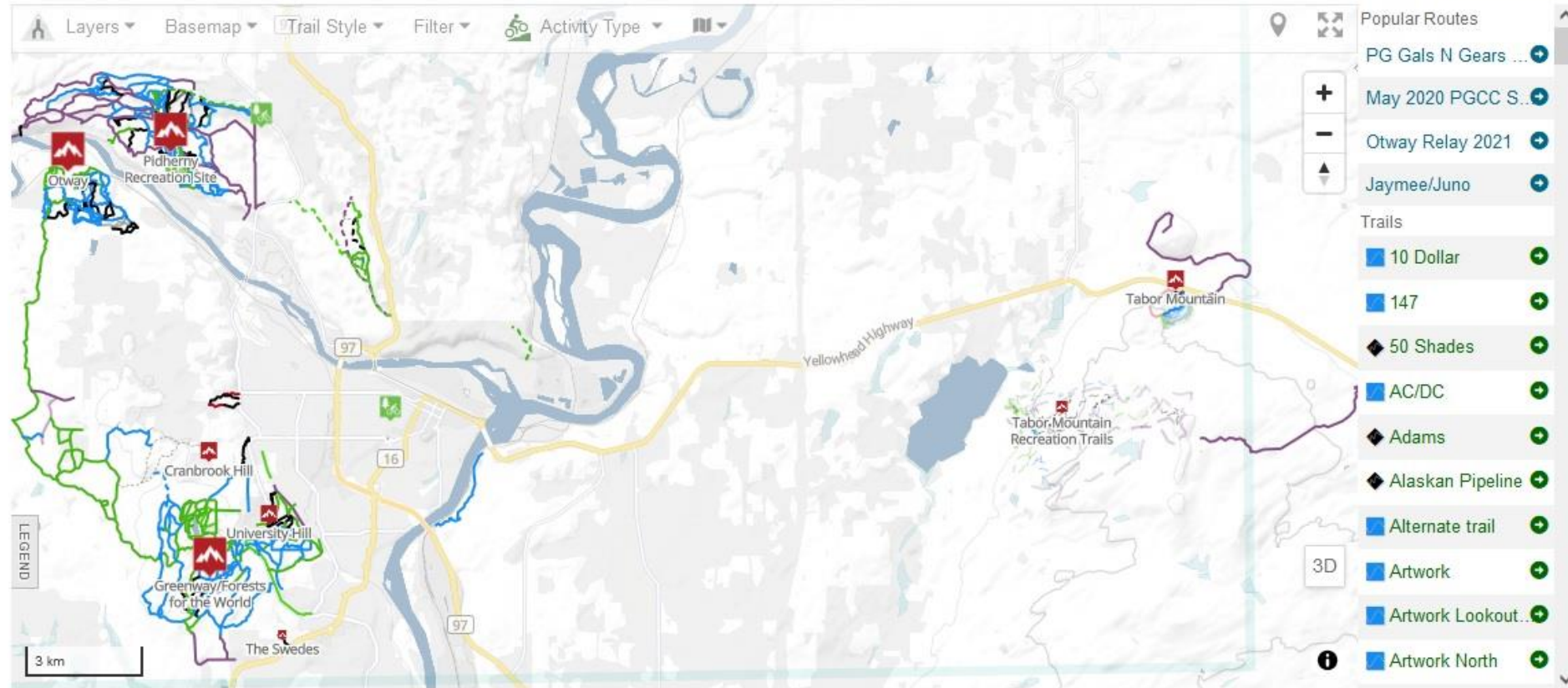
Ride Logs

Trail Usage Stats

More ▾

Add / Edit

 Layers ▾
  Basemap ▾
  Trail Style ▾
  Filter ▾
  Activity Type ▾
 



Popular Routes

PG Gals N Gears ... 

May 2020 PGCC S... 

Otway Relay 2021 

Jaymee/Juno 

Trails


10 Dollar 

147 

50 Shades 


AC/DC 

Adams 

Alaskan Pipeline 

Alternate trail 

Artwork 

Artwork Lookout... 

Artwork North 



3D



No description for Prince George has been added yet! [Login](#) or [register](#) to submit one.

Activities [Click to view](#)

Mountain Bike	E-Bike	Hike	Trail Running
302 trails	42 trails	286 trails	283 trails
ATV/ORV/OHV	Snowshoe	Nordic Ski	
8 trails	46 trails	24 trails	

<https://www.trailforks.com/region/prince-george>

GPS applications – polygons

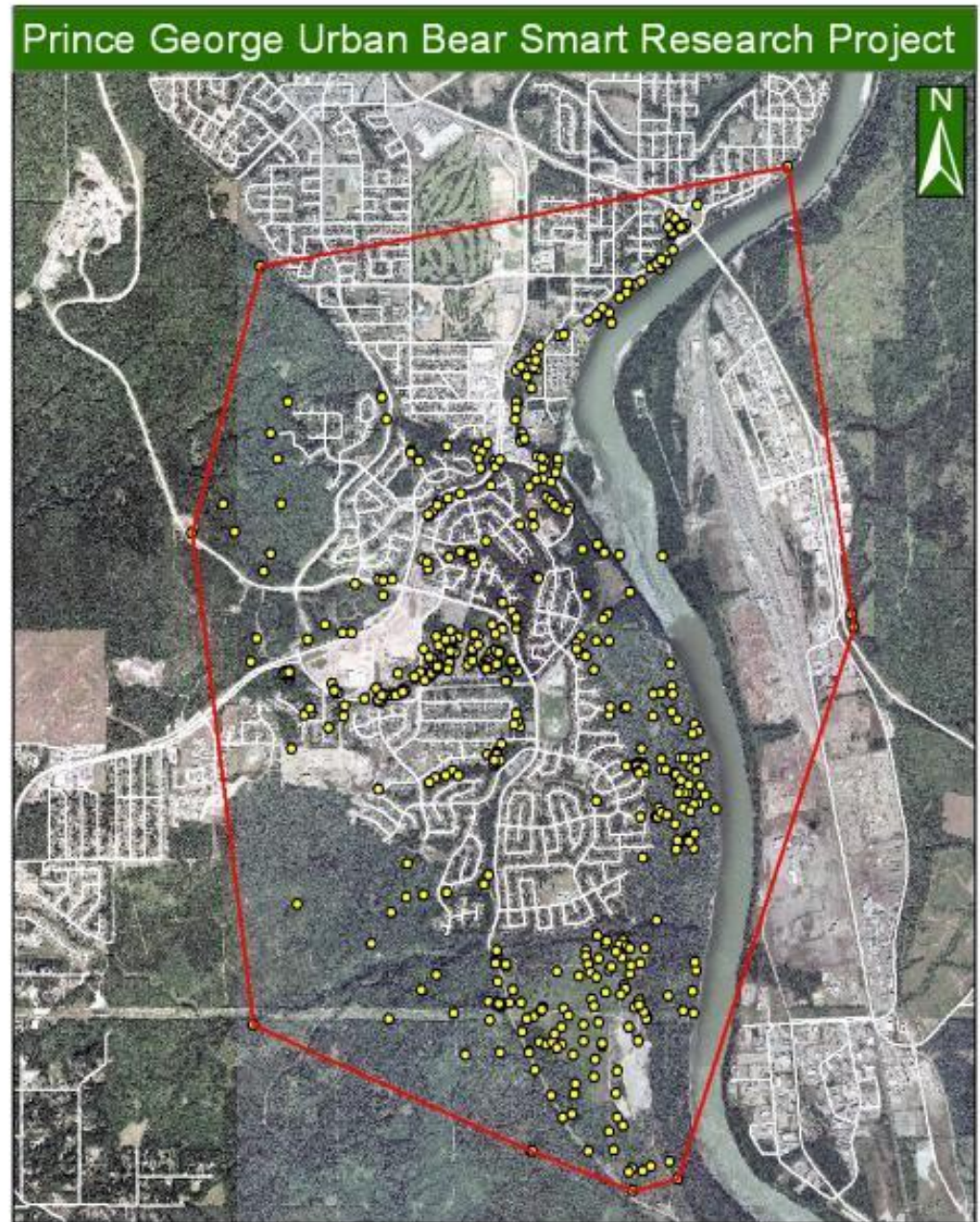


Higher accuracy required than in recreational mapping

Northern Bear Awareness Society

GPS wildlife collars - point collection

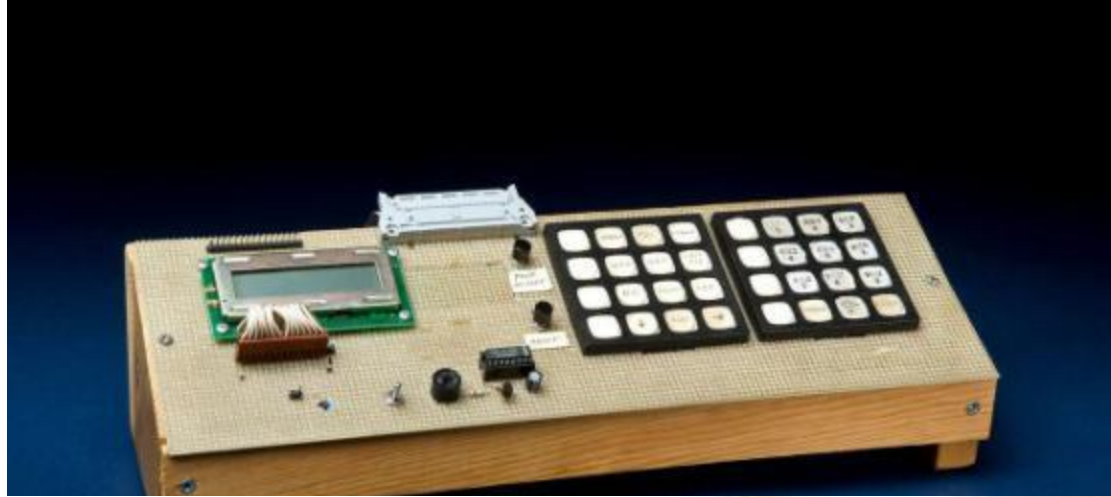
- monitor movements to minimise conflicts between predictable bears and unpredictable humans



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 GPS 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

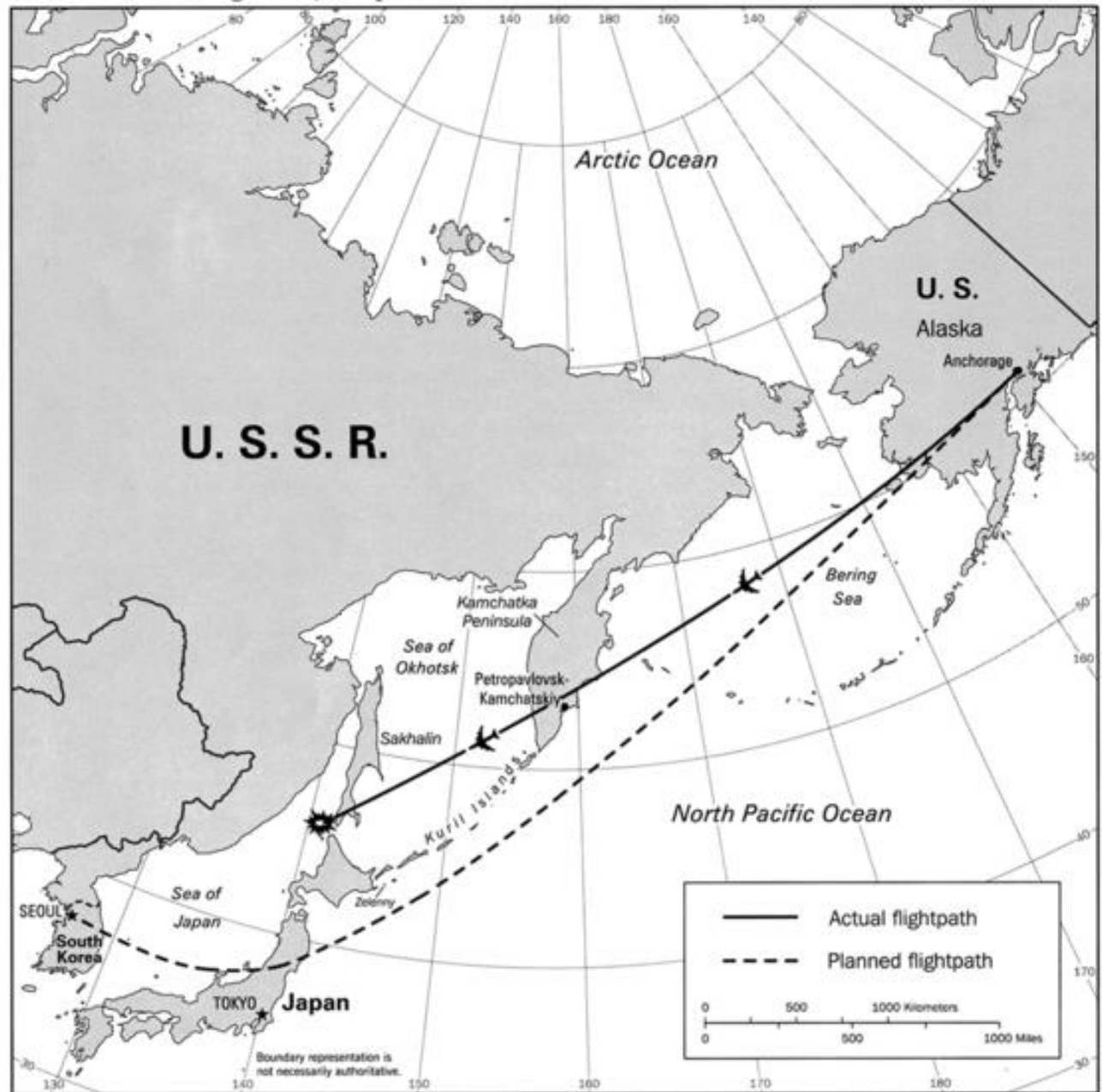
Satellites launched 1978- >

KAL 007: 269 killed

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

Initially designed to
pinpoint locations
and also reduce
civilian casualties

Korean Airlines Flight 007, 1 September 1983



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

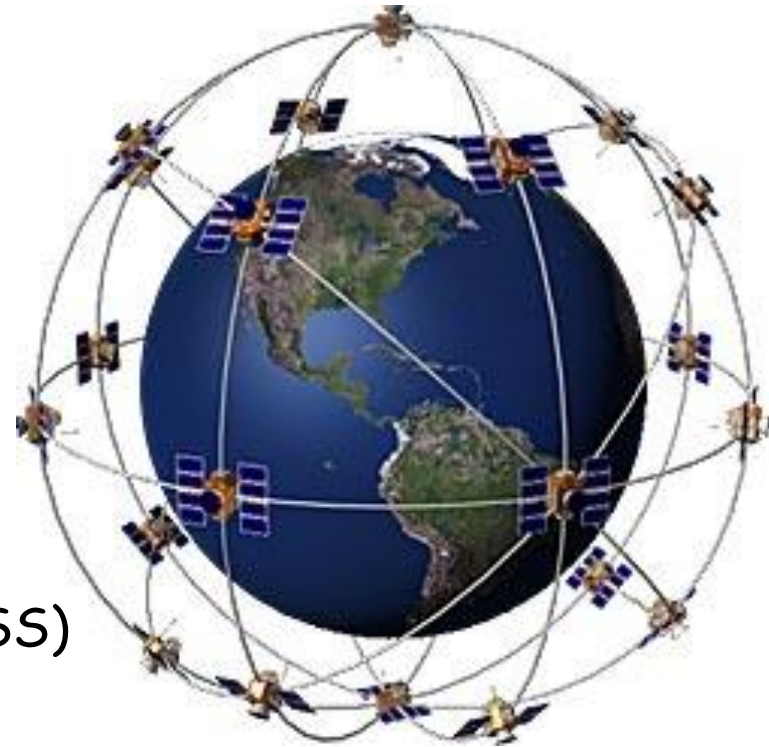
GPS is the USA system (1978)

Russia - GLONASS (1982)
Operational by 1995, Restored in 2011

Europe - Galileo (2011)

China - BeiDou (2012)

Also some regional systems e.g India (IRNSS)



GPS: 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 with relative accuracy

a. Handheld recreation units
Smartphones
\$200

5-10



b. Resource/map grade units
\$2000

1-5 m



c. Survey grade units
\$10,000

1mm - 1m



True accuracy relies on several factors - see below

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

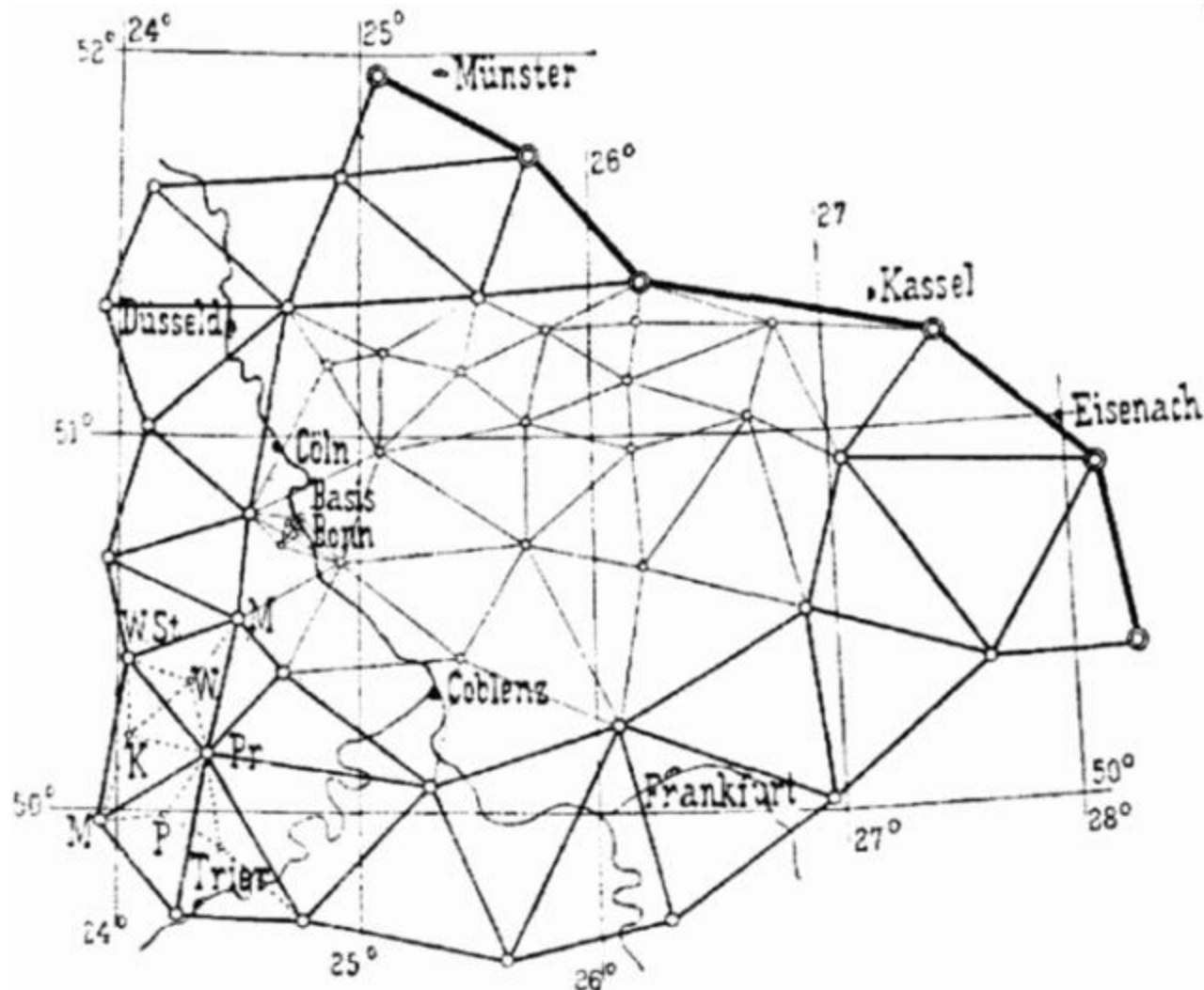
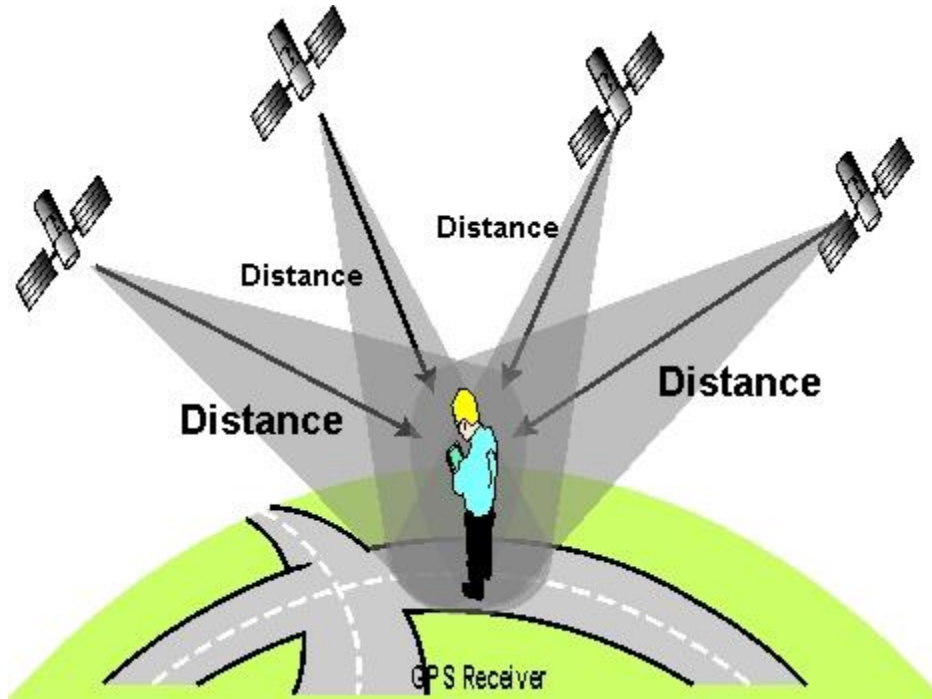


Fig. 4. Die rheinisch-hessische Kette und das nieder-rheinische Dreiecksnetz.

GPS Trilateration



Code is transmitted many thousand times a second and includes

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

$$\text{Distance} = \text{Time} \times \text{Speed}$$

(Speed = 300,000 km/sec)

Atomic clocks measure time in seconds to 10 decimal places

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

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

GPS unit multiplies the time by the speed of light to determine how far signal travelled from satellite

Software combines the > 4 readings to generate a ground location

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

Location coordinates can be recorded by the GPS as:

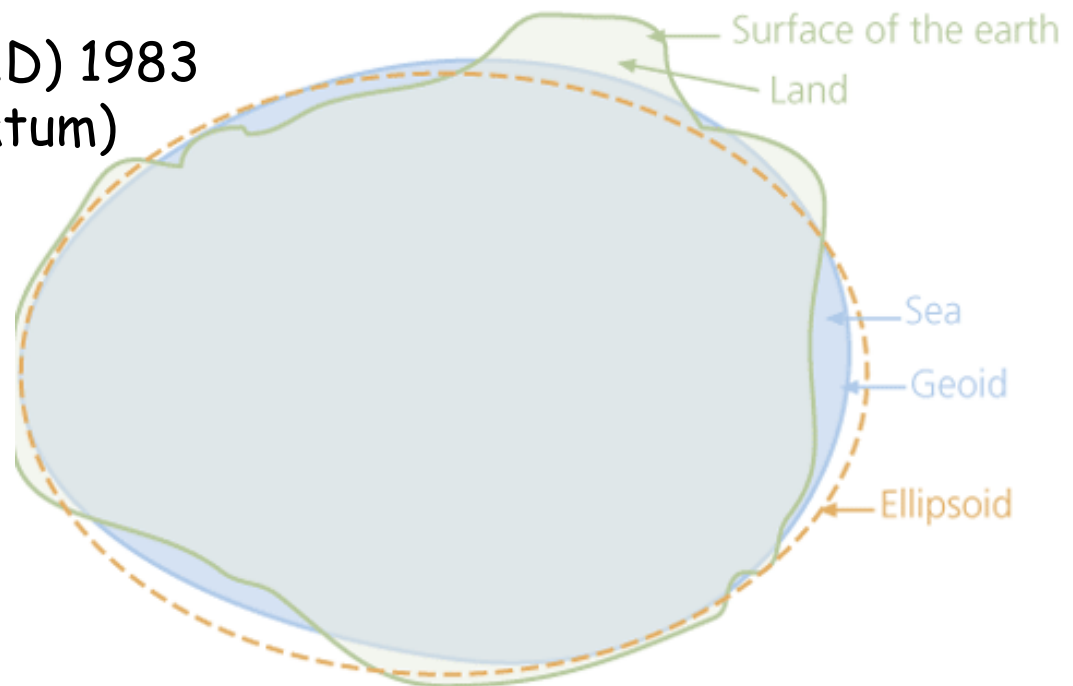
- Latitude / Longitude - D/M/S or decimal degrees OR
- UTM eastings and northings, with zone (in metres)

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

- WGS (World Geodetic System) 1984

Model of the Earth

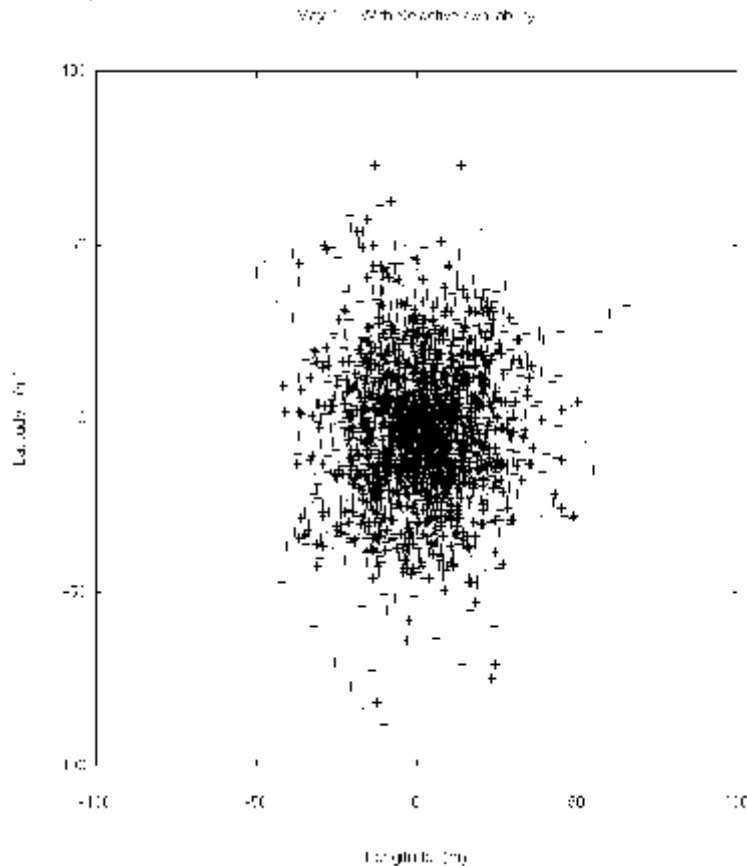
- North American Datum (NAD) 1983
(local mapping reference datum)



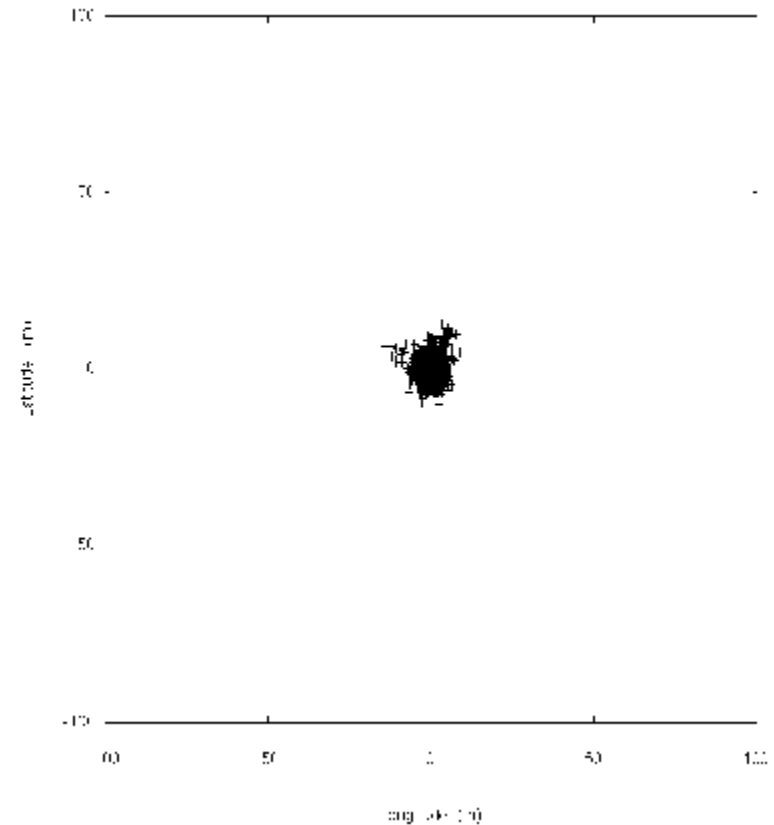
GPS terms: 1. Selective Availability (SA)

- 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 = 3.1234567000

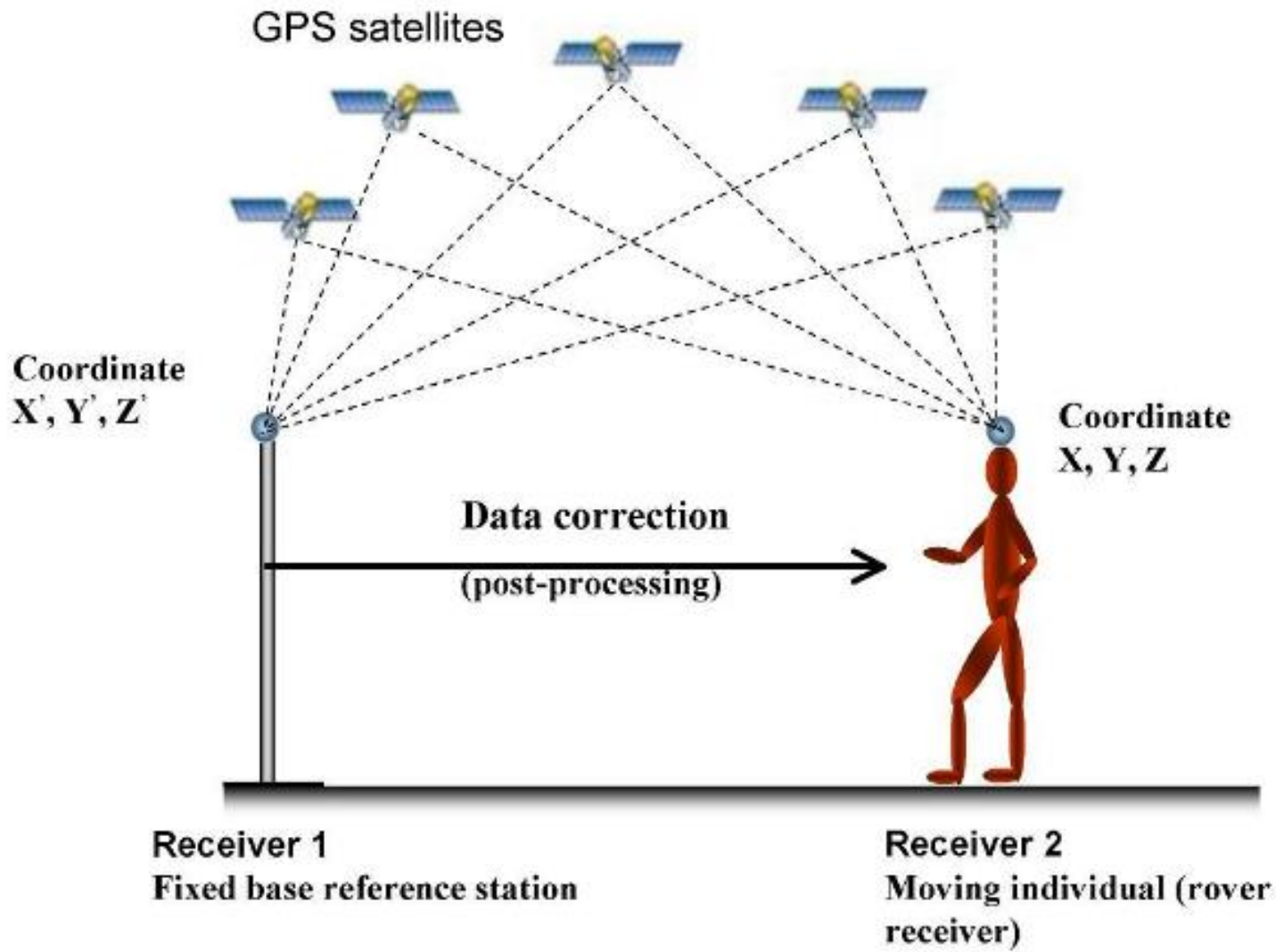
May 1, 2000 - Selective Availability on



May 3, 2000 - Selective Availability Off



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



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



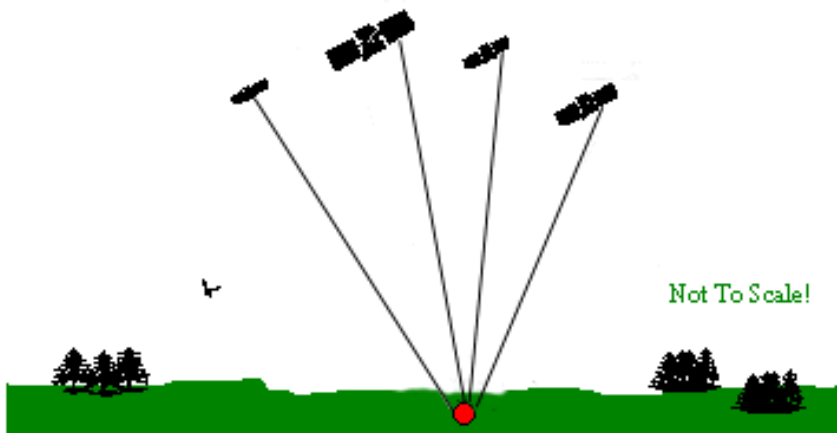
3. (Percent) Dilution of Precision

- 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

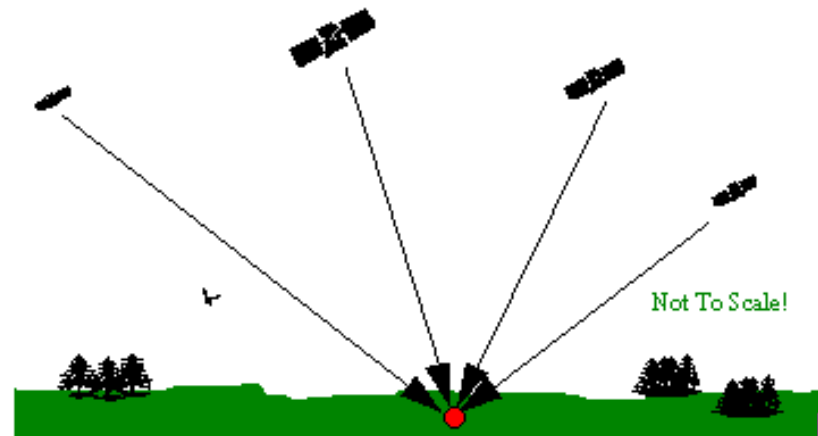
PDOP < 4.0 : excellent

Poor Dilution of Precision



High DOP (poor)

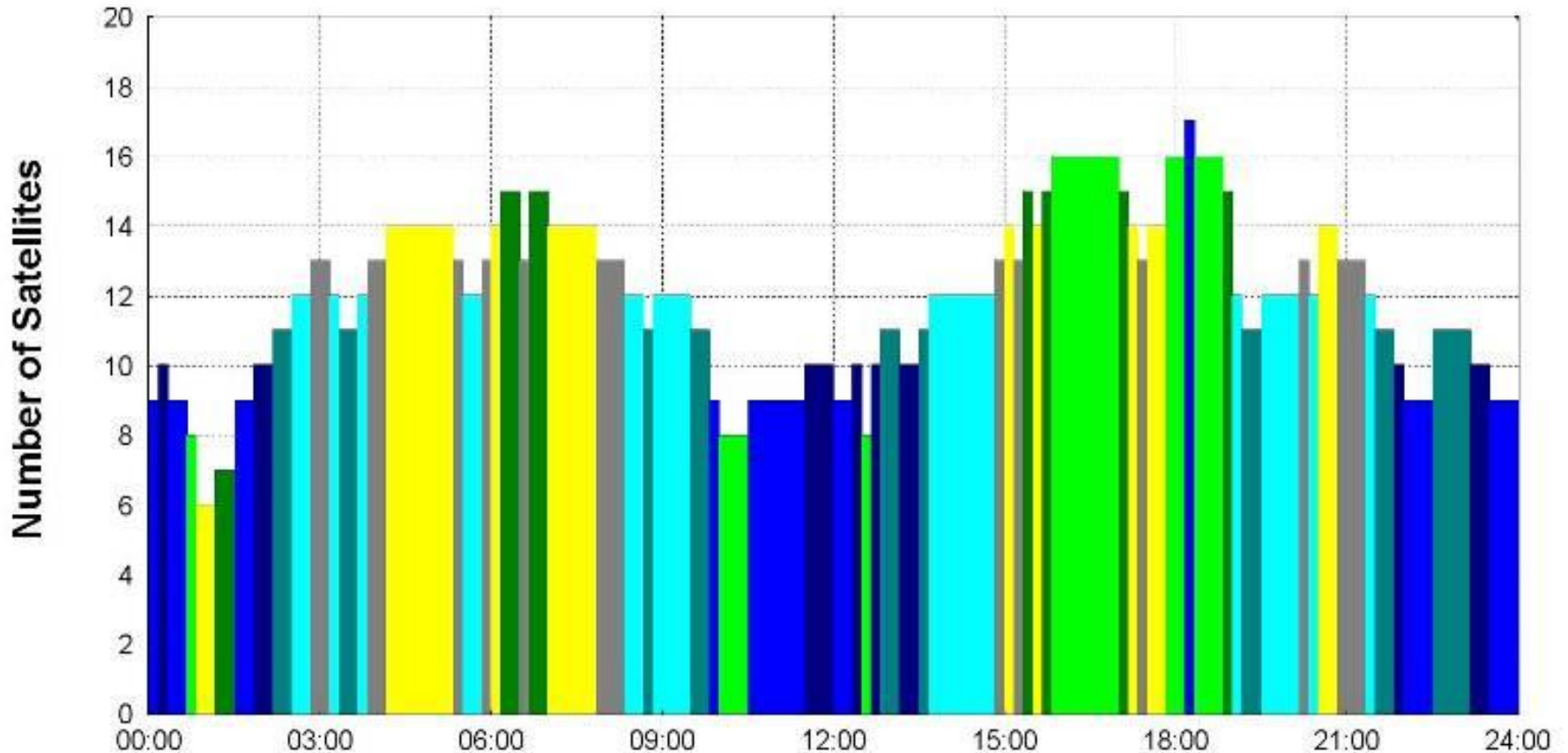
Good Dilution of Precision



Low DOP (good)

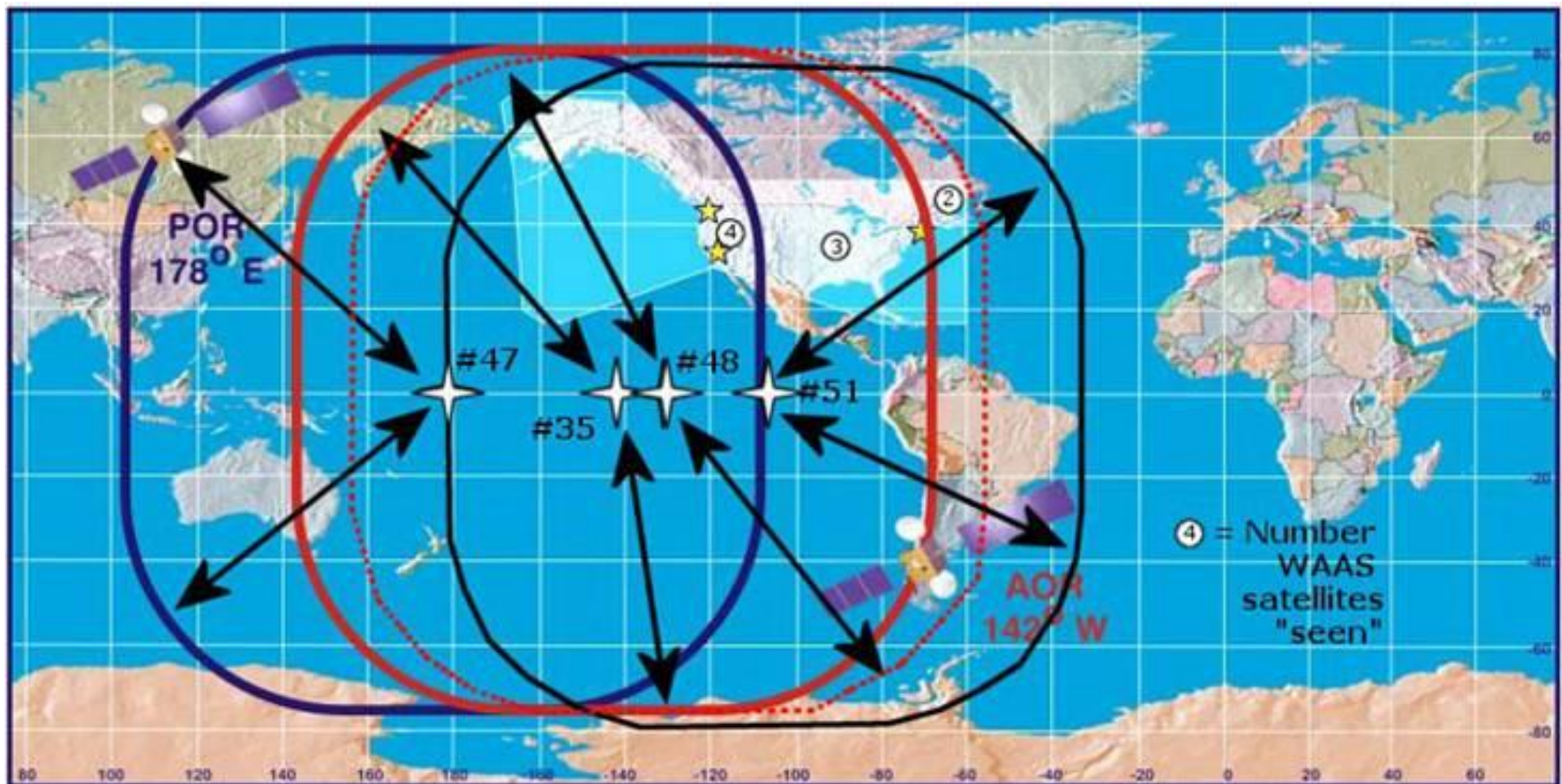
of satellites (affects PDOP)

Visibility

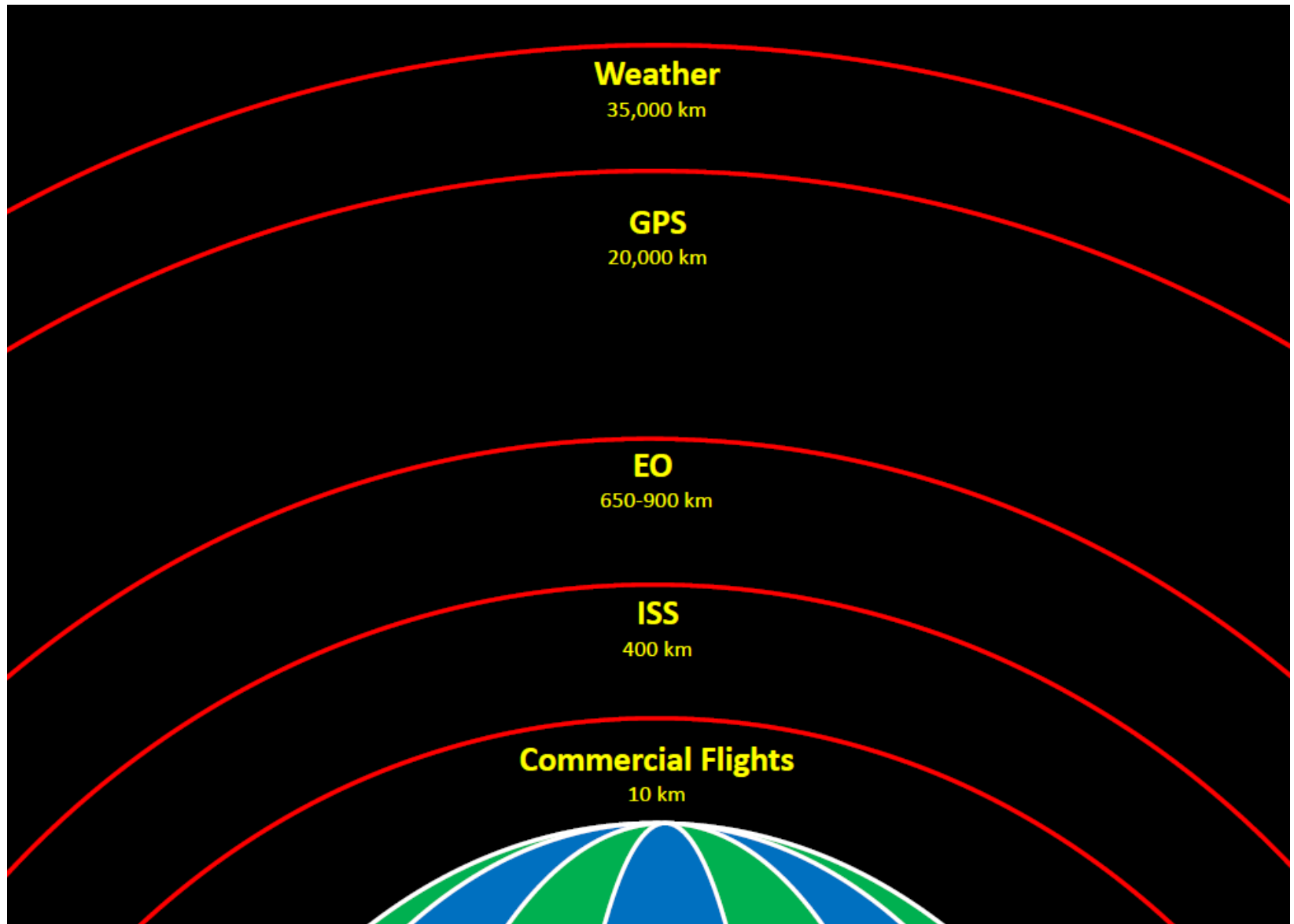


WAAS (Wide Area Augmentation System) Geostationary Satellites (since 2003)

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*



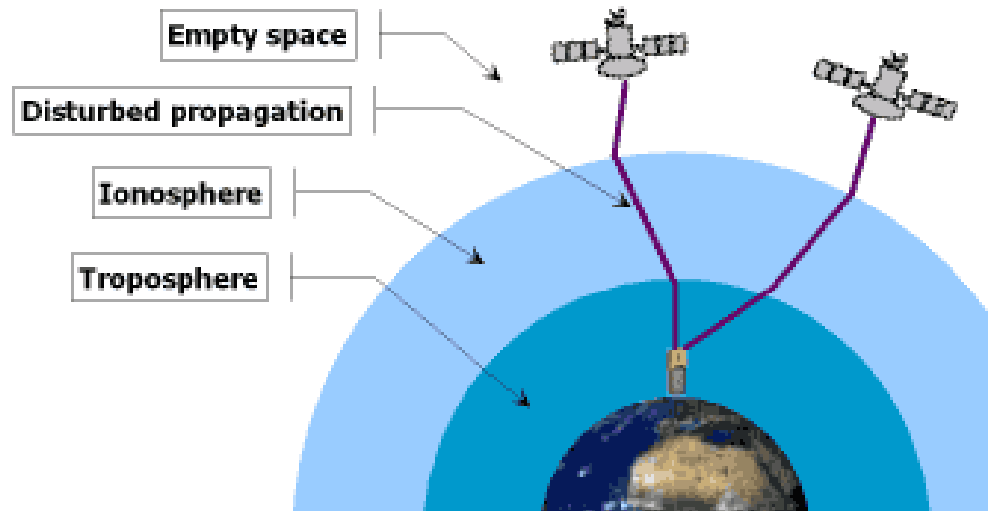
Earth from Space: Earth Observation (EO) satellites



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

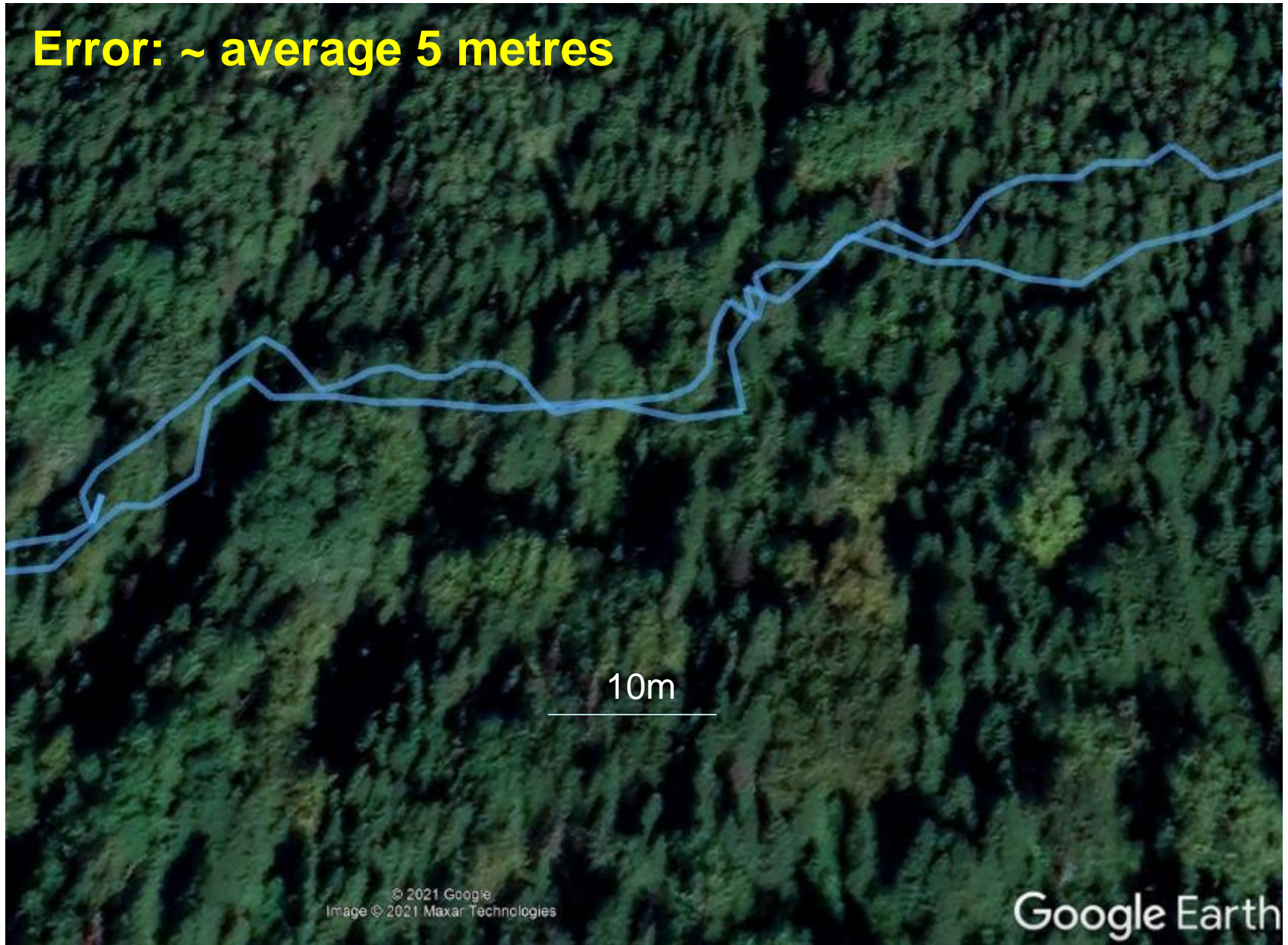
We use DGPS to help remove these errors ...

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

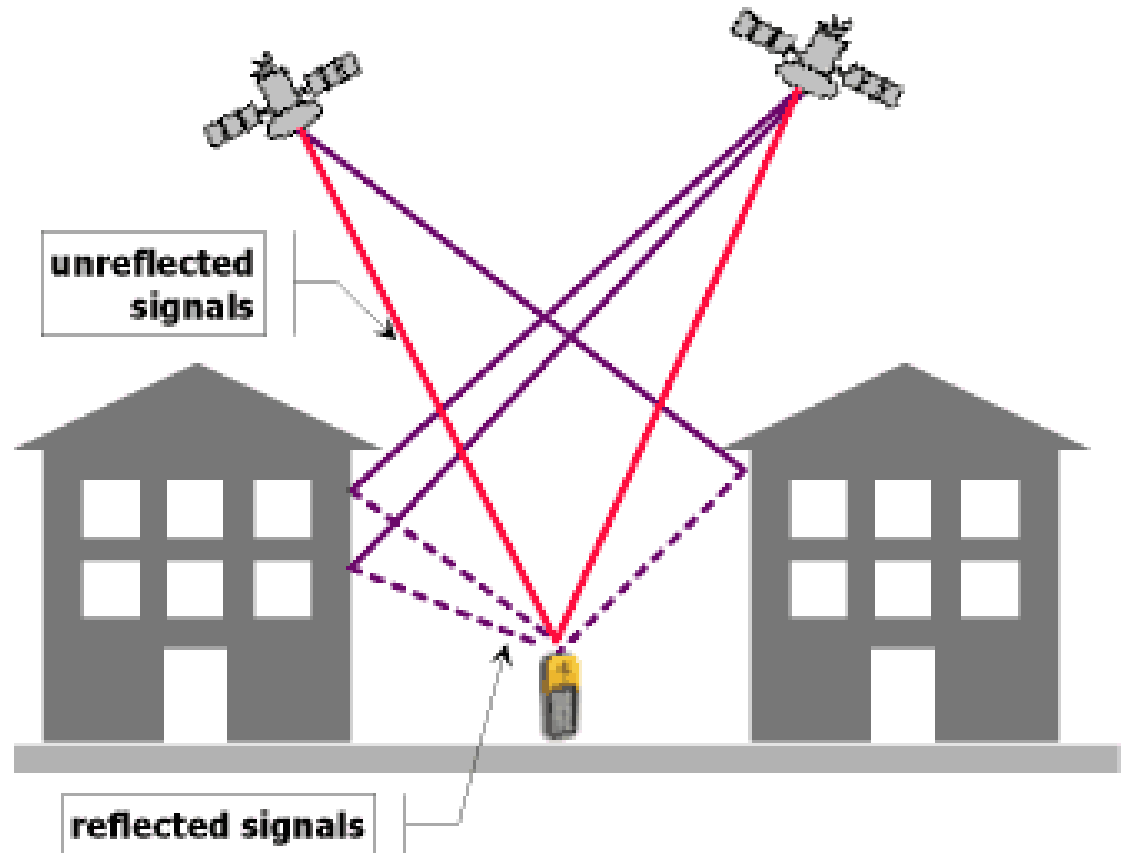
You can reduce error by taking the average of many readings e.g. at trail junctions

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

Error: ~ average 5 metres



Multipath: GPS is line of sight



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

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: 51.24542307241623

Longitude: -115.83992958068848

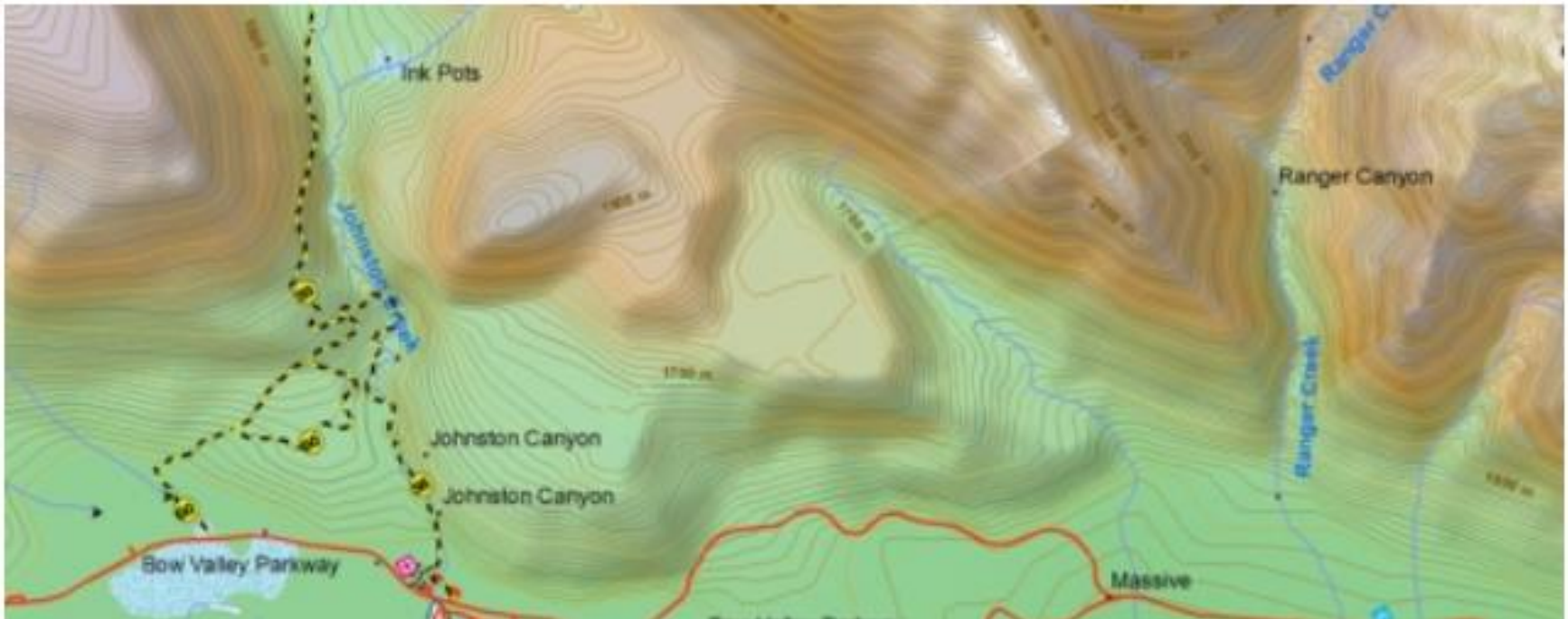
14 decimal places !

-too precise; NOT accurate

-not enough **generalization**

Last digit = millionths of a mm

Detailed Map

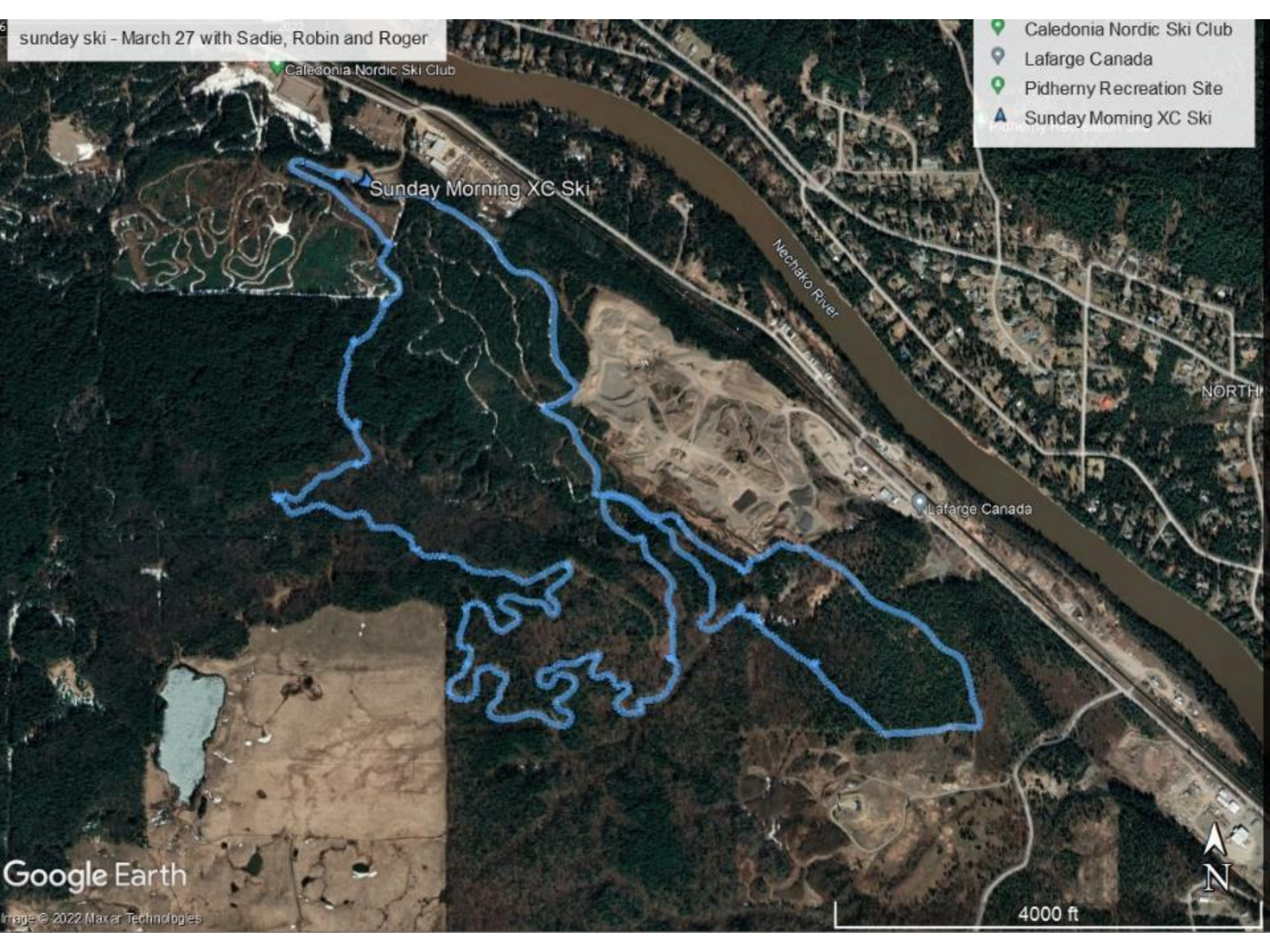


Beware e.g. GPS directions along Cranbrook Hill Road



Mapped and updated by local users using GPS





sunday ski - March 27 with Sadie, Robin and Roger

Caledonia Nordic Ski Club

Sunday Morning XC Ski

Nechako River

Lafarge Canada

NORTH

- Caledonia Nordic Ski Club
- Lafarge Canada
- Pidherny Recreation Site
- Sunday Morning XC Ski

Google Earth

Image © 2022 Maxar Technologies

4000 ft



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

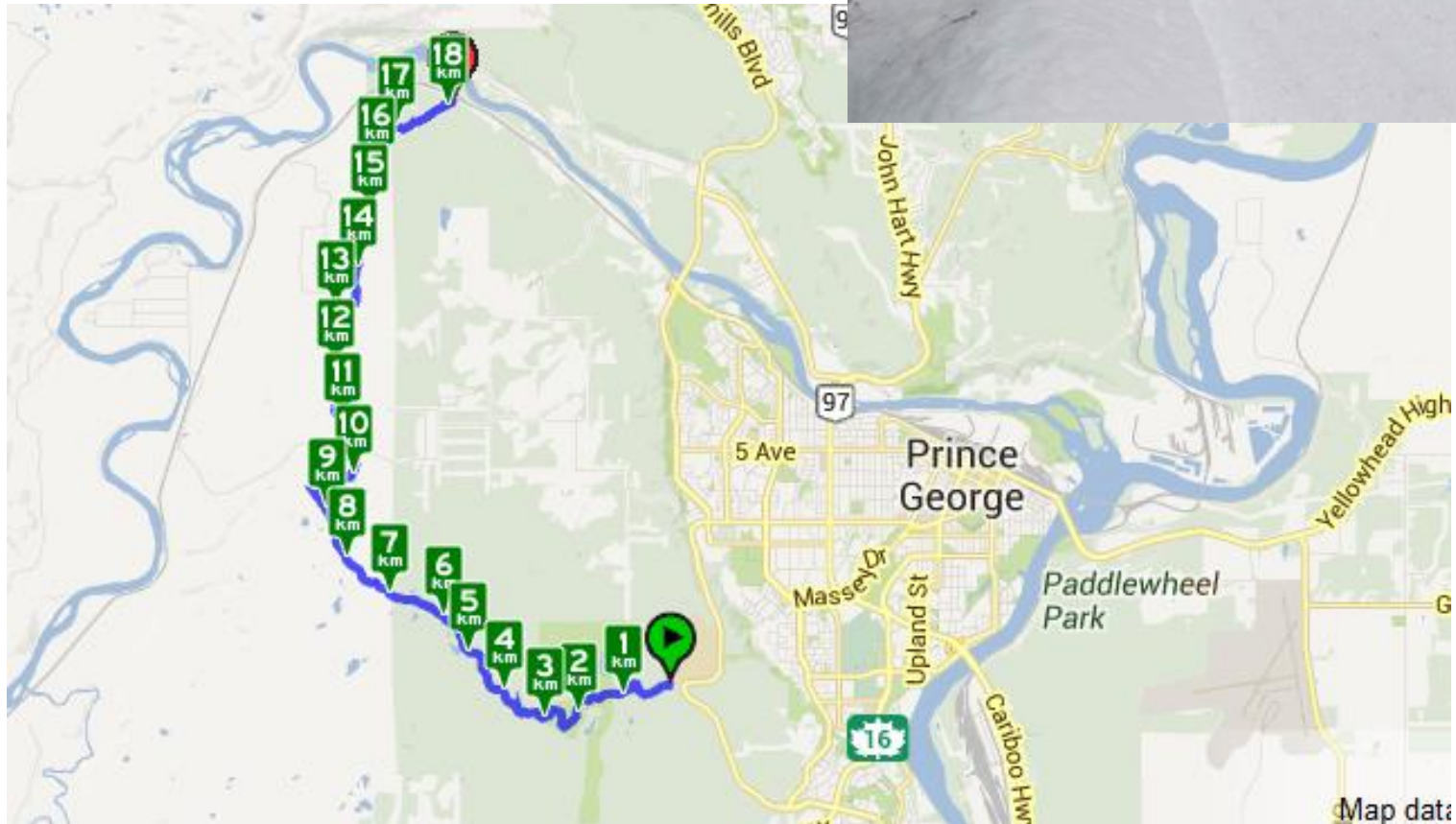
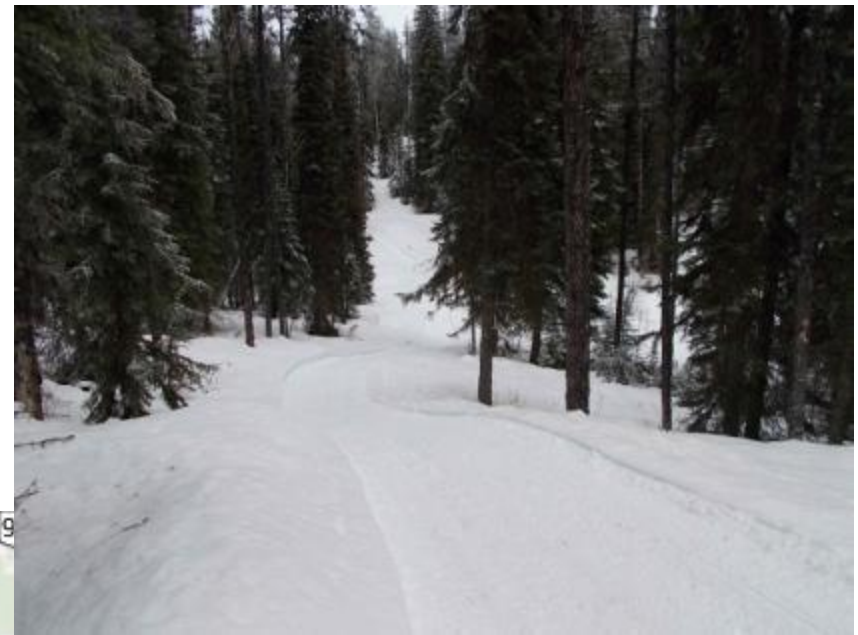


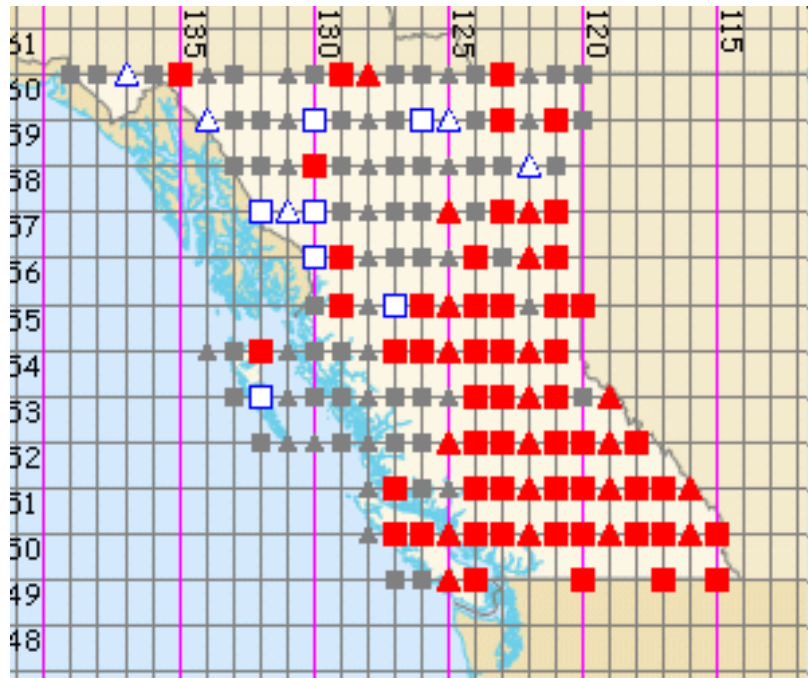
GPS data input:

<http://openstreetmap.org>

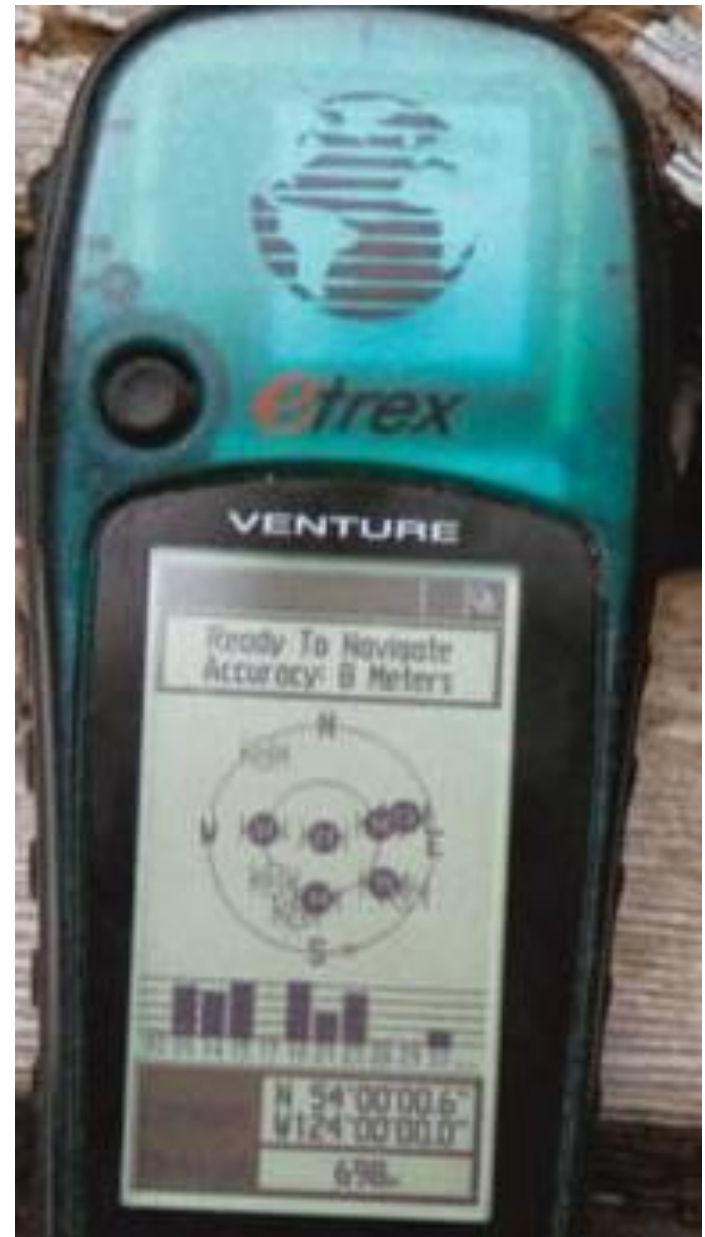
<http://www.mapmyrun.com>

<https://www.geocaching.com>





54N, 124W: 1.8 km (1.1 miles) SSE of Vanderhoof, BC, altitude: 695 m (2280 ft)



Public mapping every degree intersection:

<http://confluence.org>