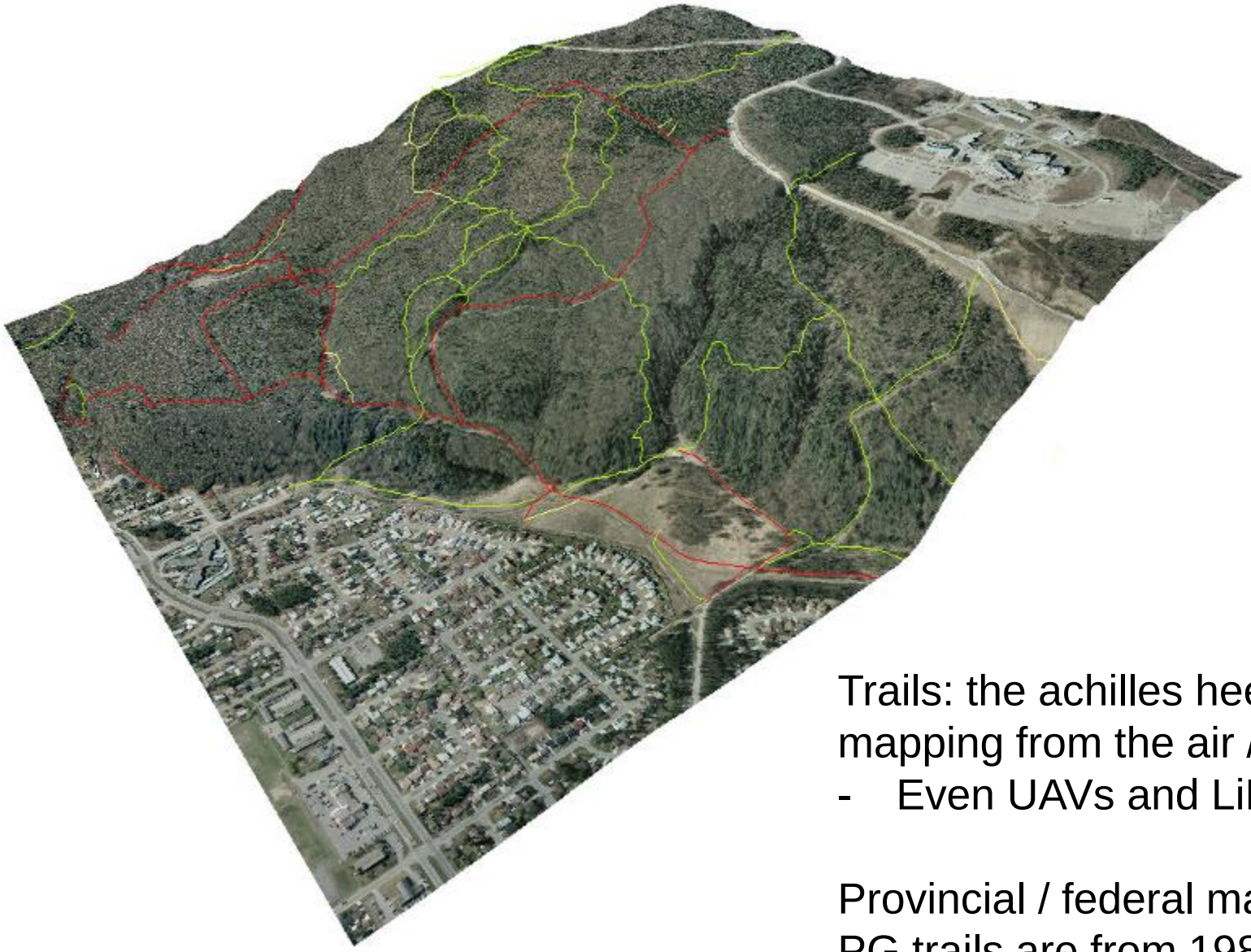
Global Positioning Systems (GPS)

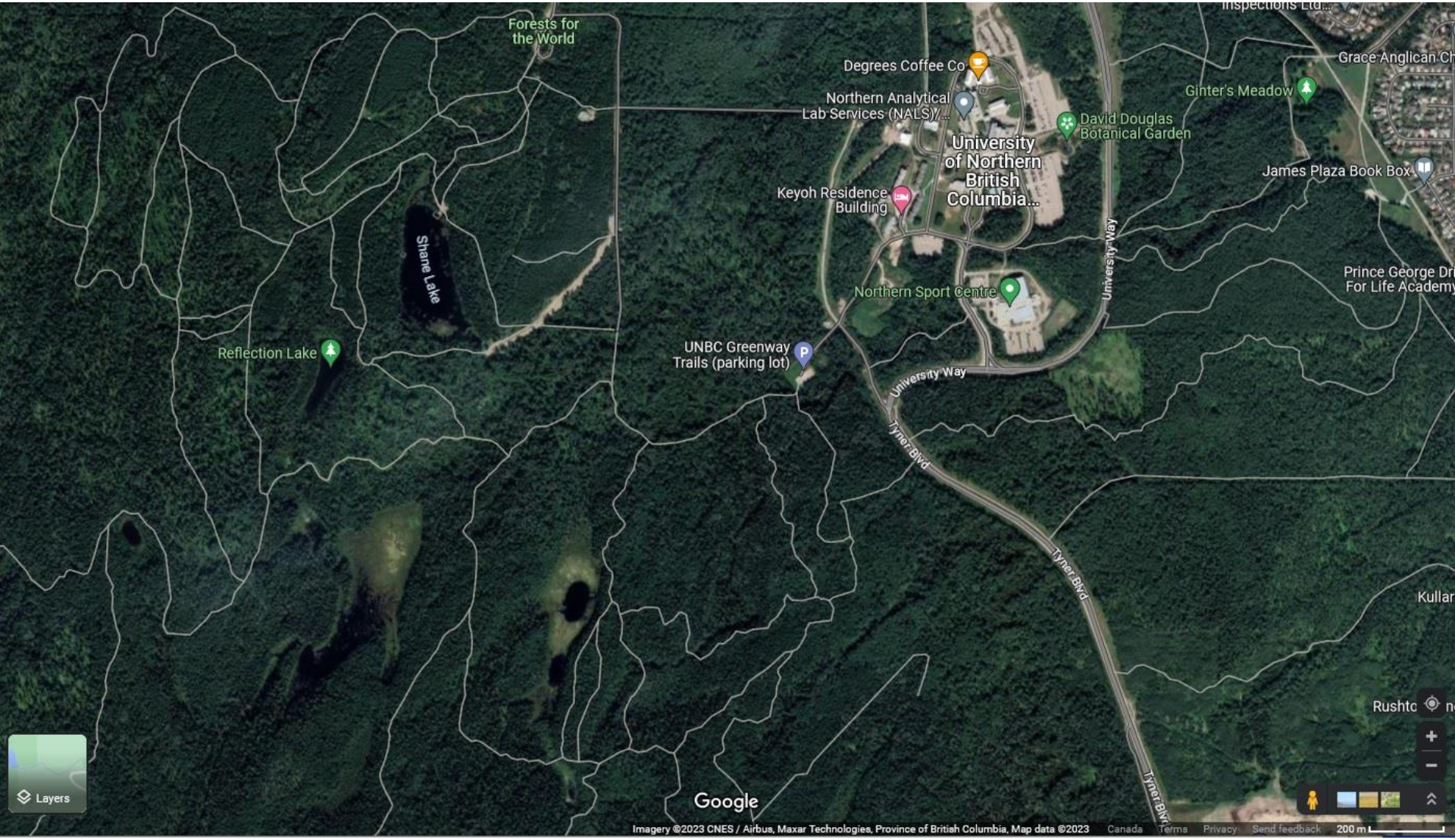


Trails: the achilles heel of mapping from the air / satellites

- 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



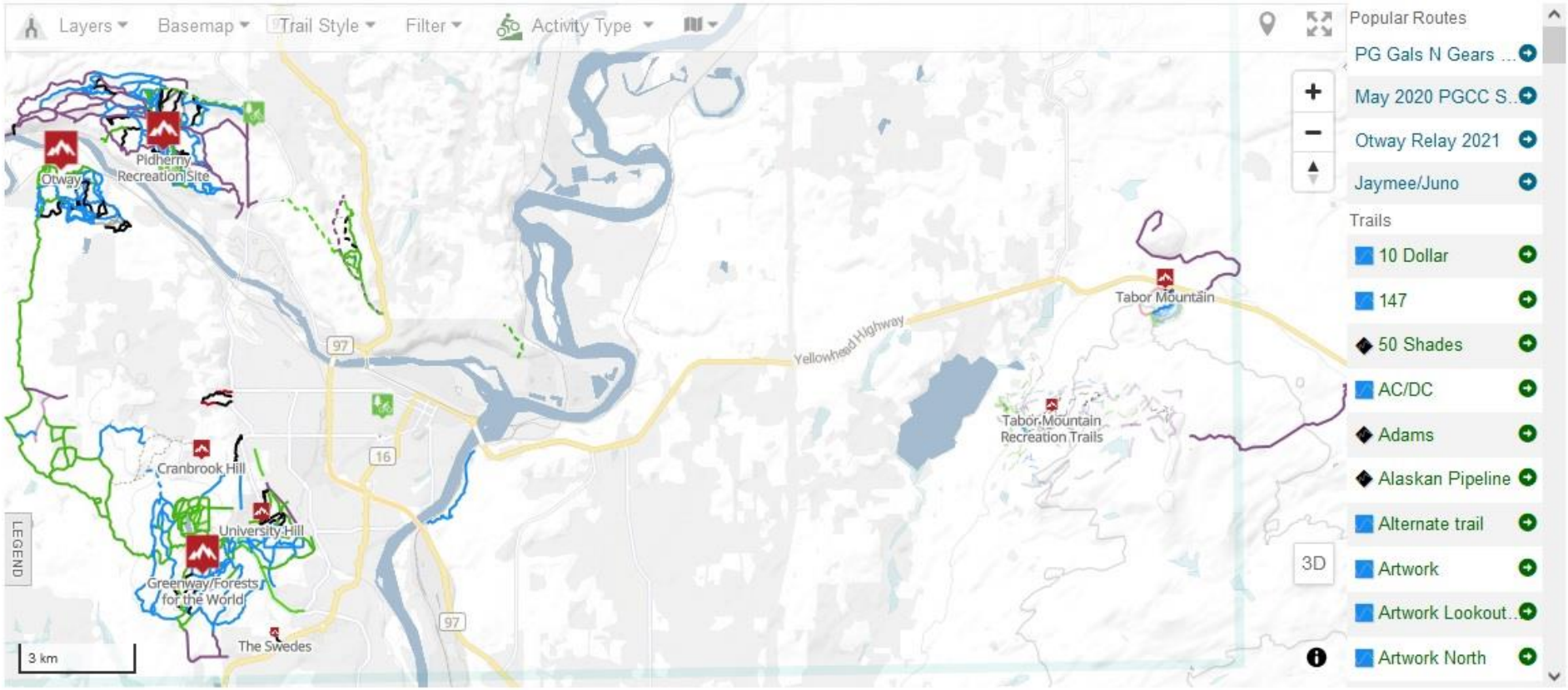
Mapped and updated by local users using GPS

Nearby | Trails | Routes | Reports | Parks | Ride Log | Events | Apps | More | Outside | Get Trailforks Pro

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



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

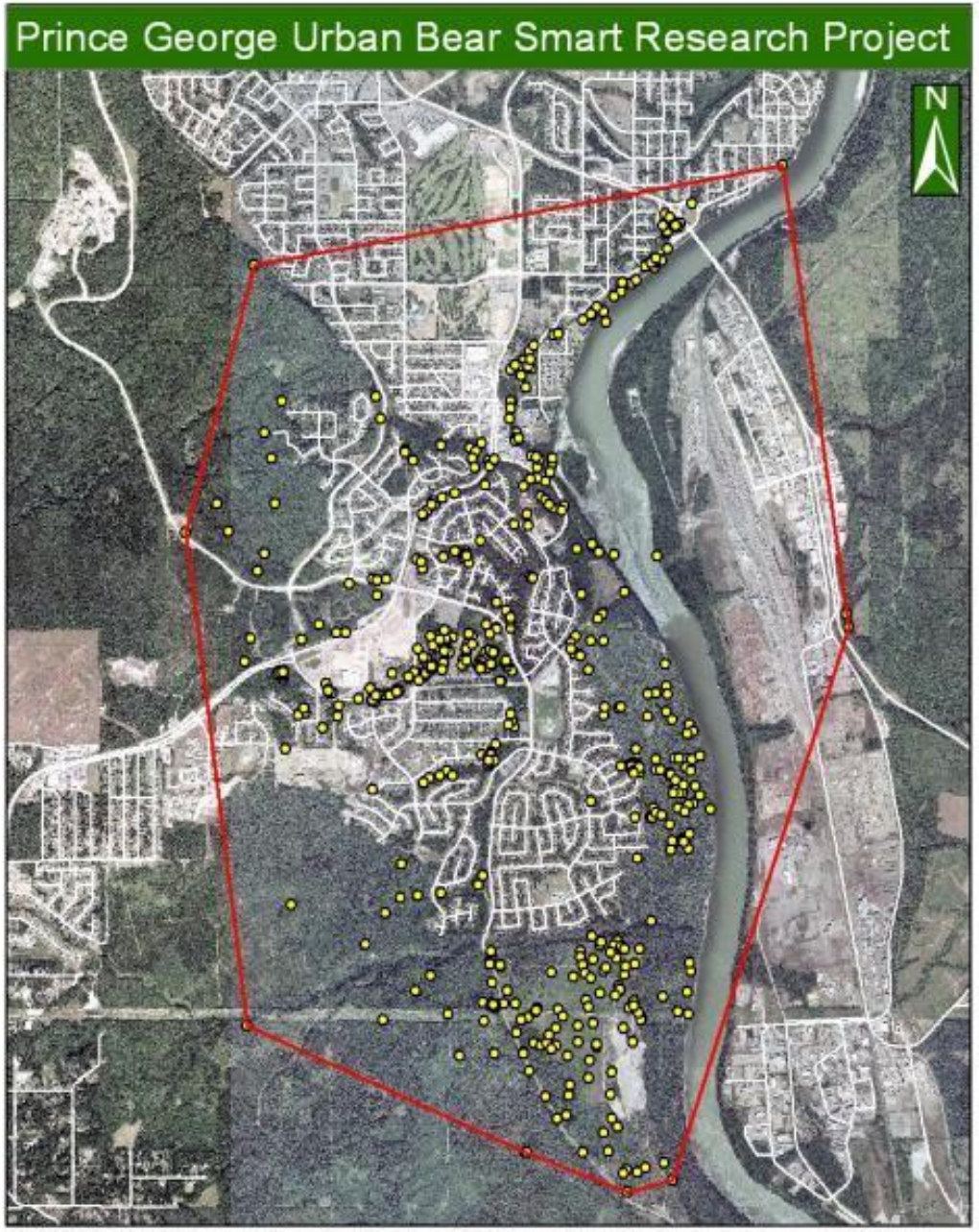
GPS applications – polygons

Higher accuracy required than in recreational mapping

Northern Bear Awareness Society

GPS wildlife collars - point collection

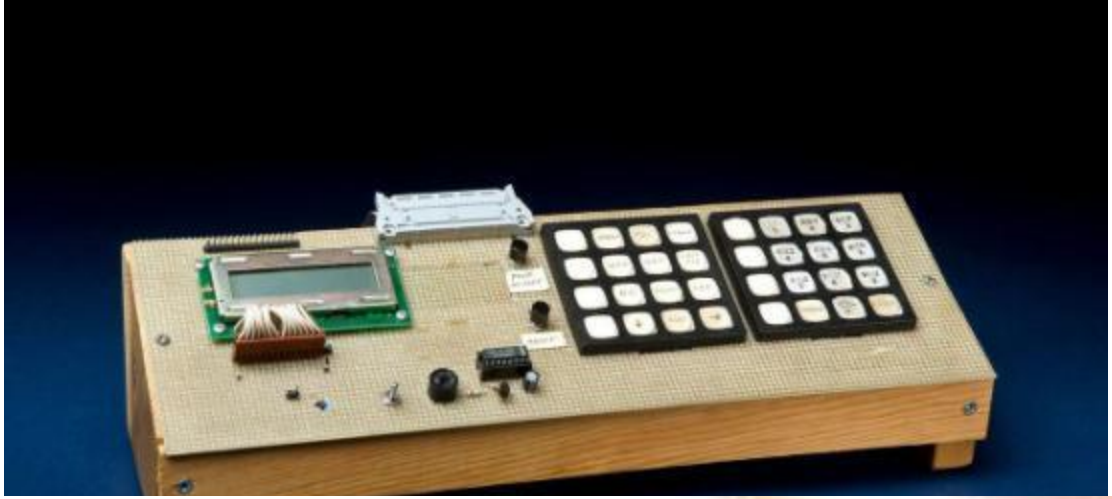
- monitor movements to minimise conflicts between predictable bears and unpredictable humans



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

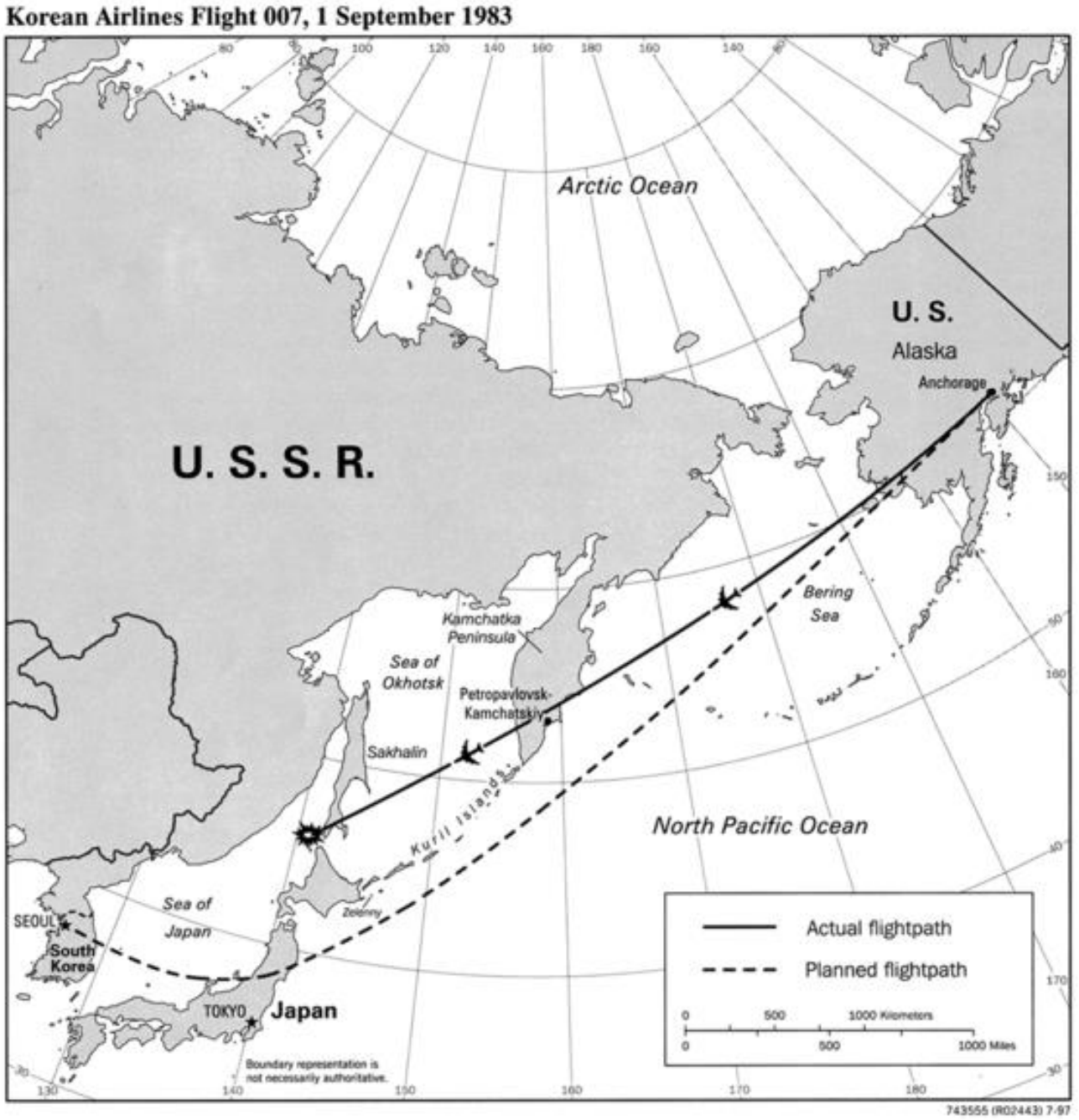
list of satellites:
http://en.wikipedia.org/wiki/List_of_GPS_satellites

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



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

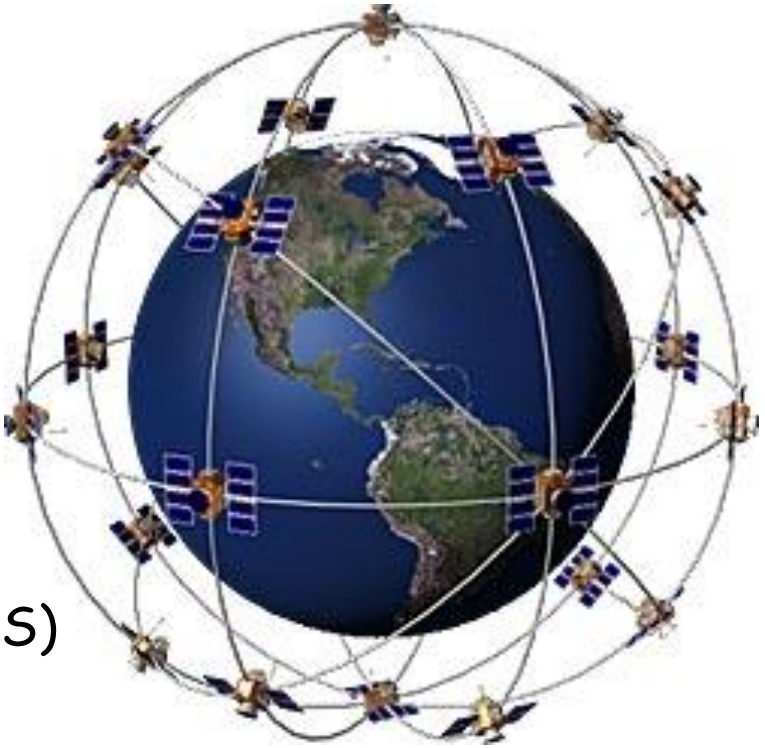
GPS is the USA system (1978)

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 5-10m

Smartphones

$200

b. Resource/map grade units 1-5 m

$2000

c. Survey grade units 1mm – 1m

$10,000

True accuracy relies on several factors – see below

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

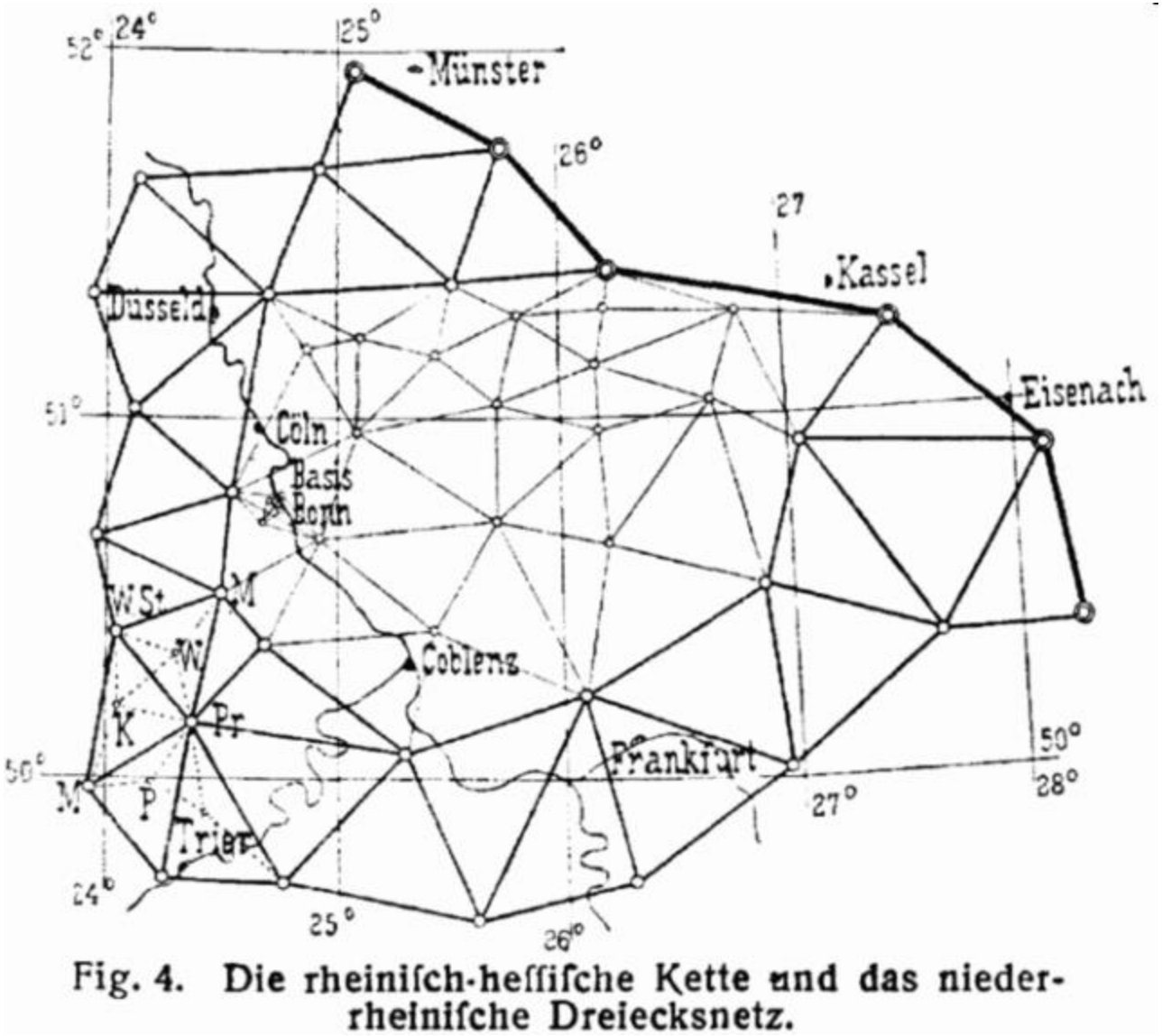
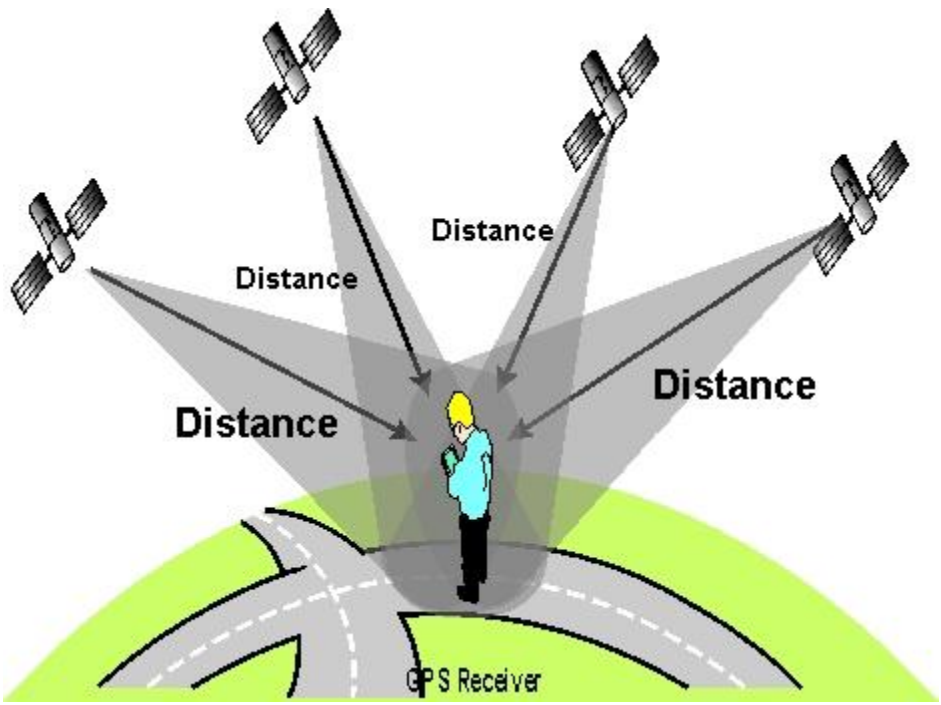


Fig. 4. Die rheinisch-hessische Kette und das niederrheinische Dreiecksnetz.

GPS Trilateration



Code is transmitted many thousand times a second and includes

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

Distance = Time x 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

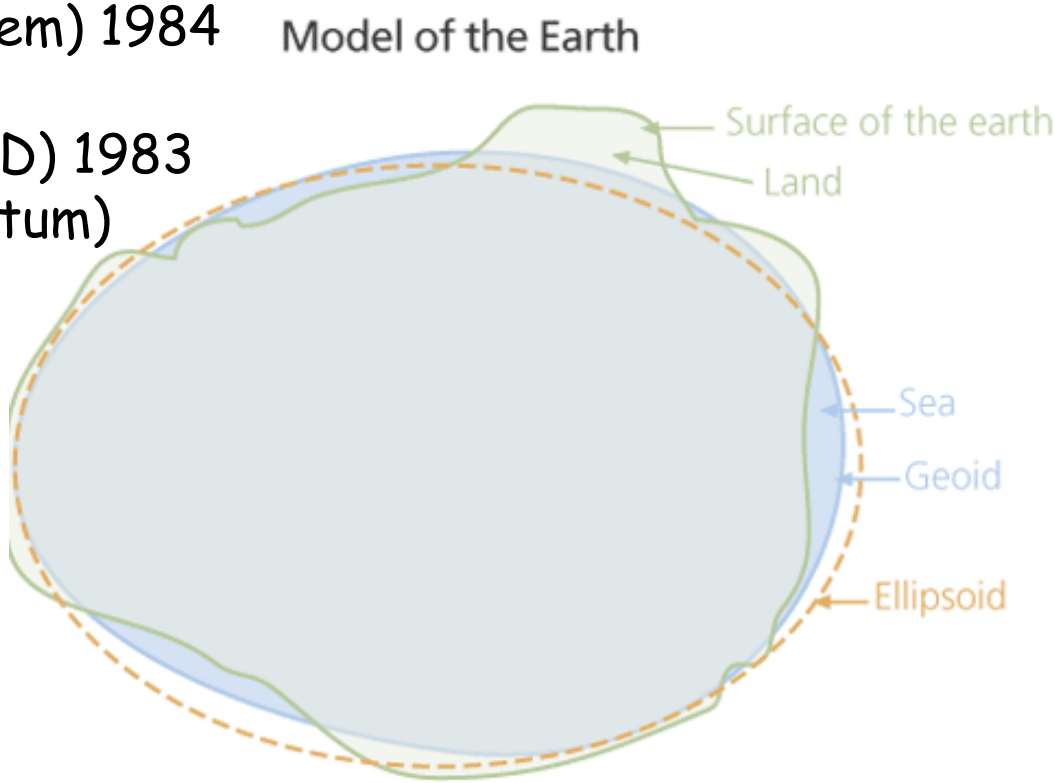
Solves for x, y, z and 'time'
– uncertainty of ground clock

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):

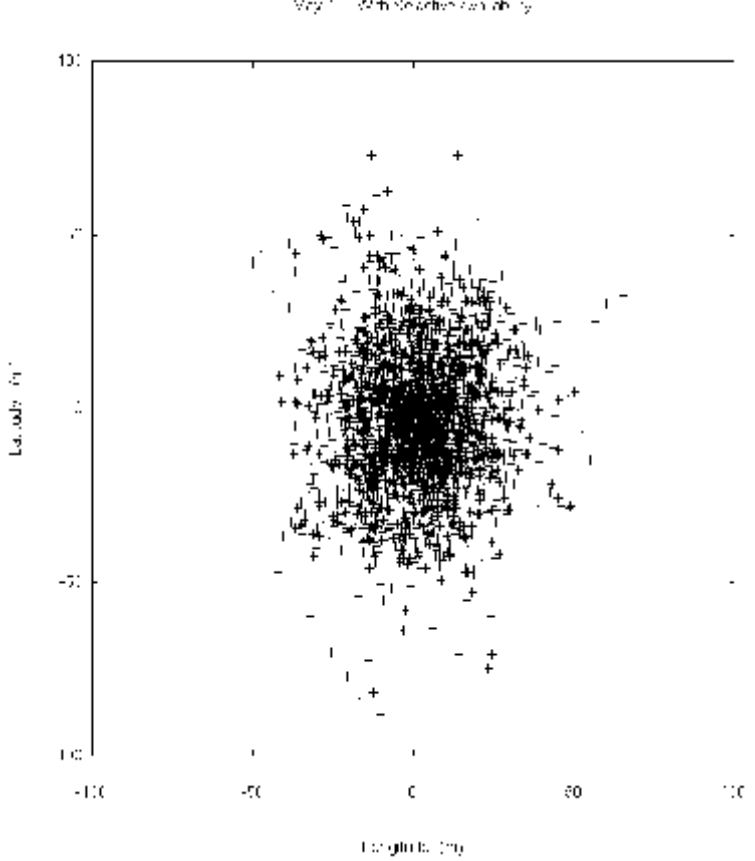
- WGS (World Geodetic System) 1984
- North American Datum (NAD) 1983
  (local mapping reference datum)



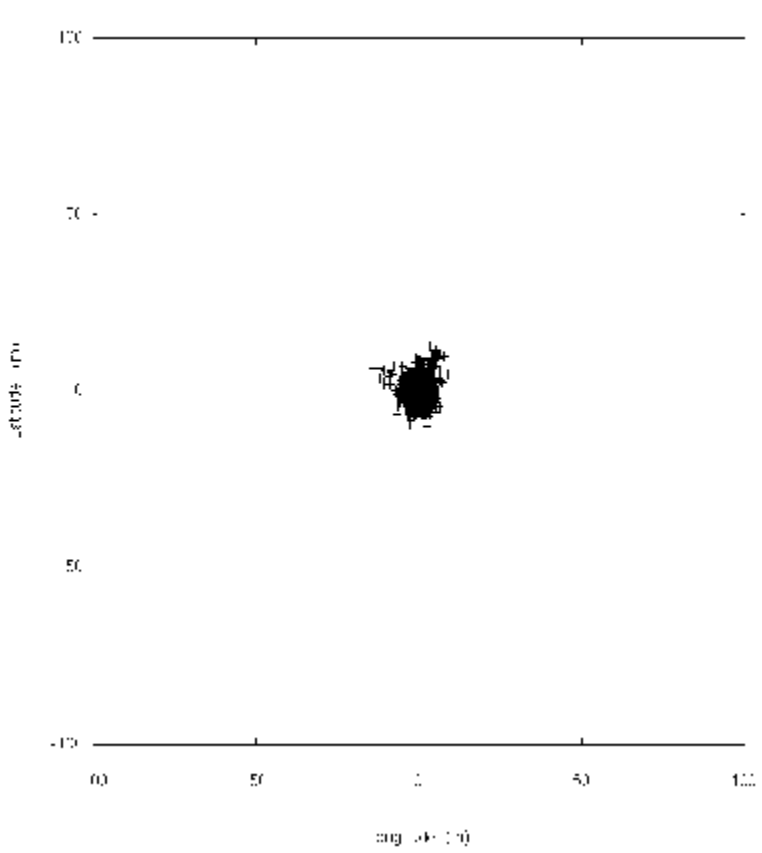
GPS terms: 1. Selective Availability (SA)

- 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

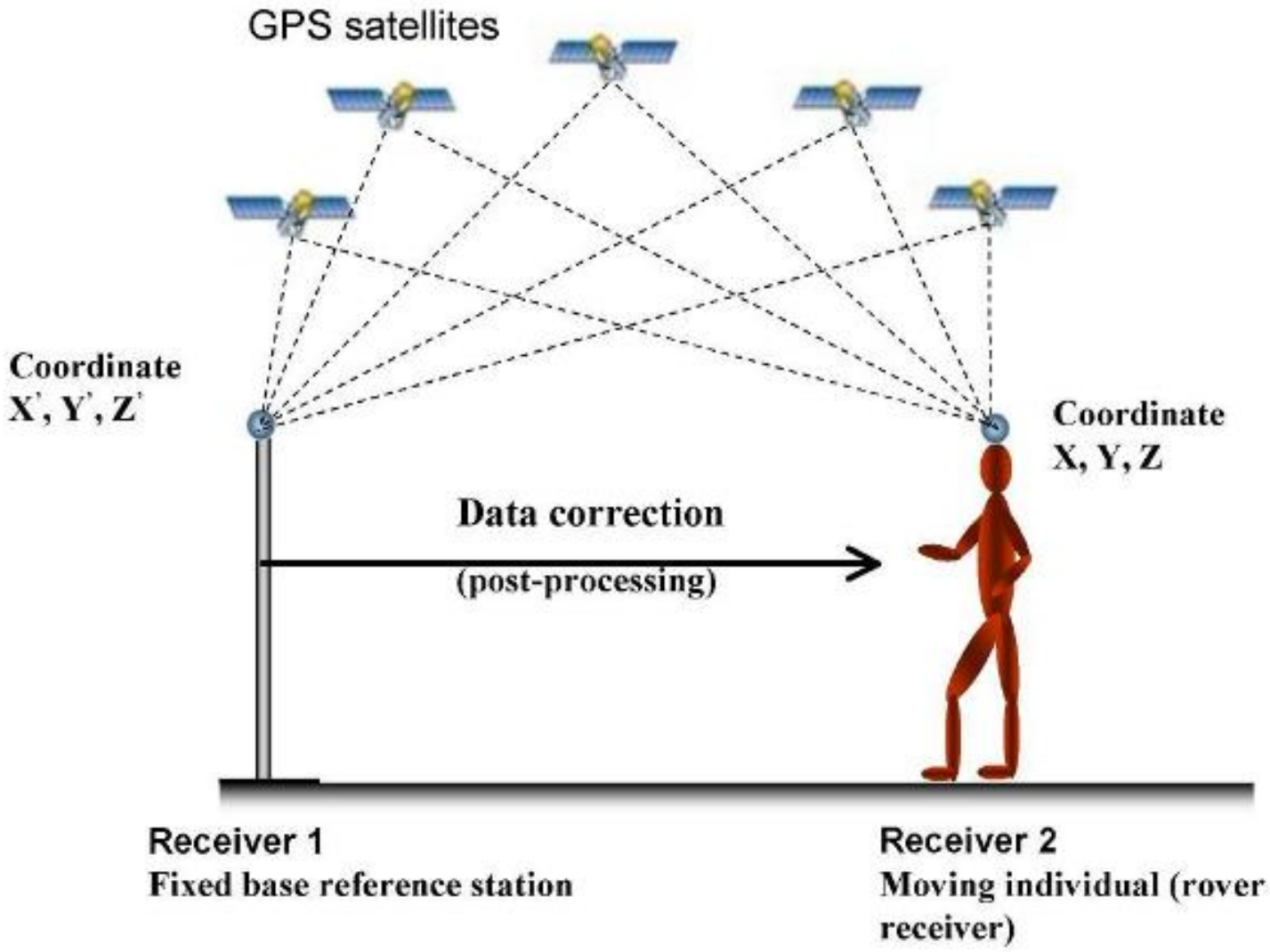
May 1, 2000 – Selective Availability on



May 3, 2000 – Selective Availability Off



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

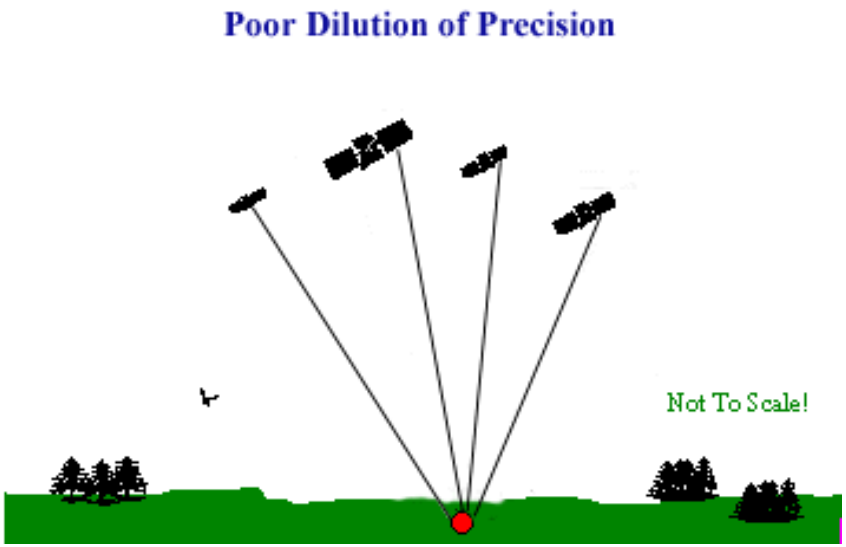


Base station, Coast Mountains, Mt. Waddington – real-time DGPS

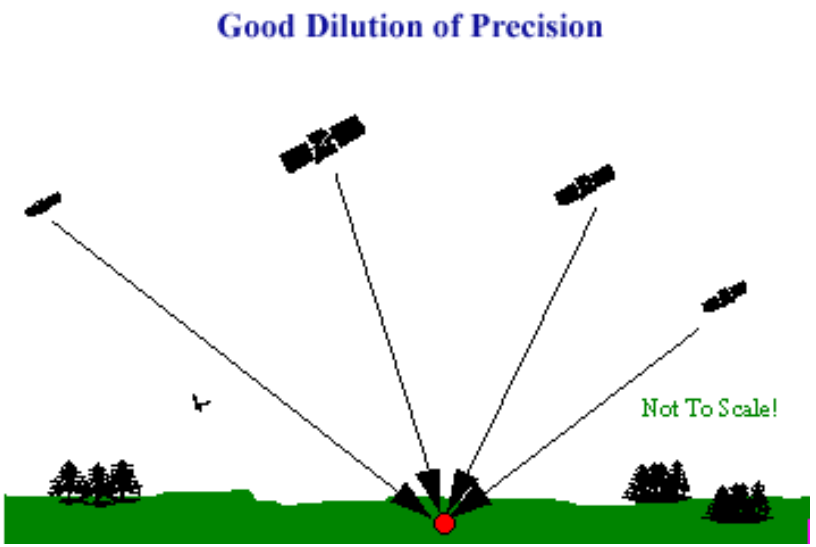
3. (Percent) Dilution of Precision

- **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**

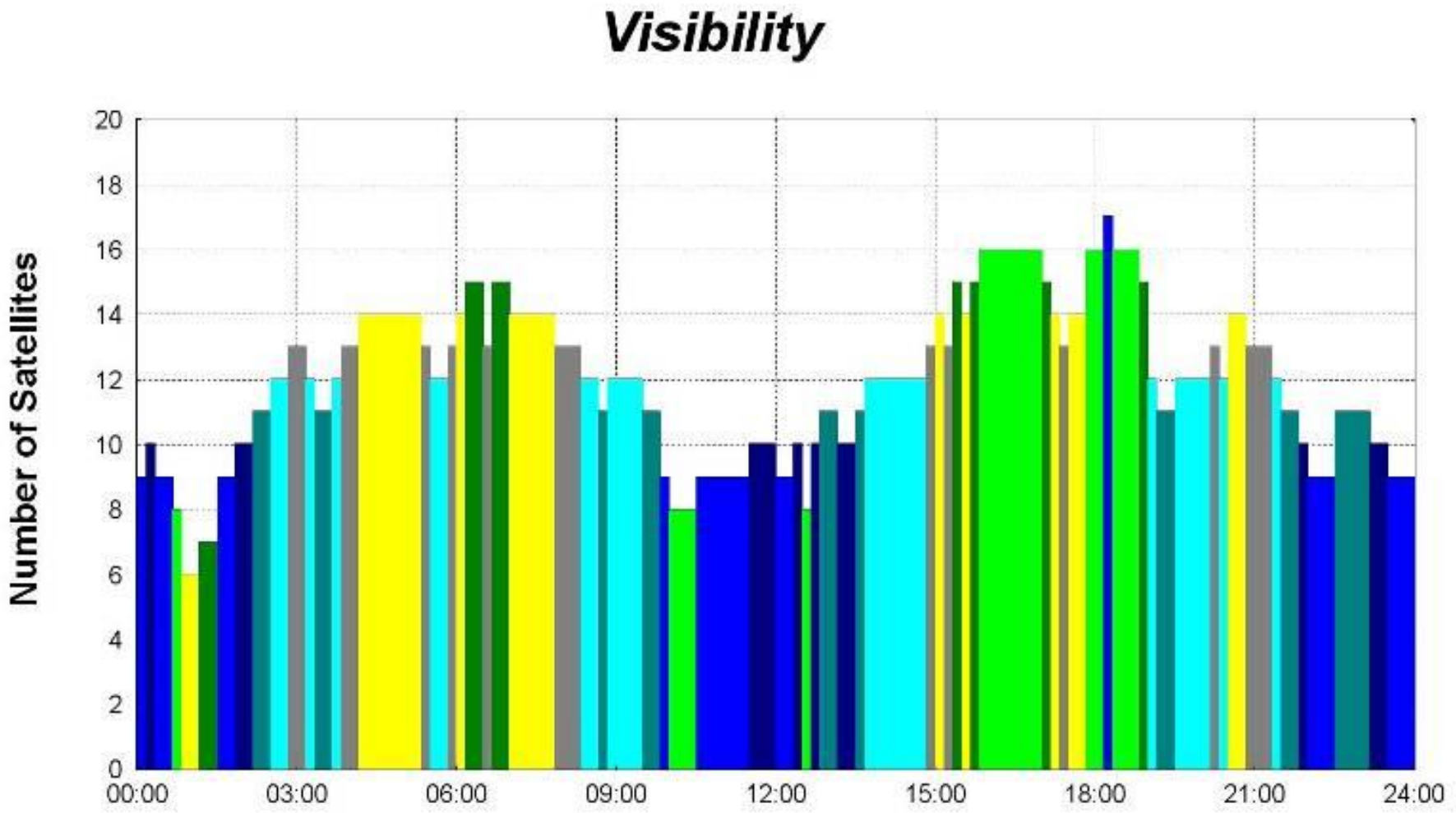


High DOP (poor)



Low DOP (good)

of satellites (affects PDOP)

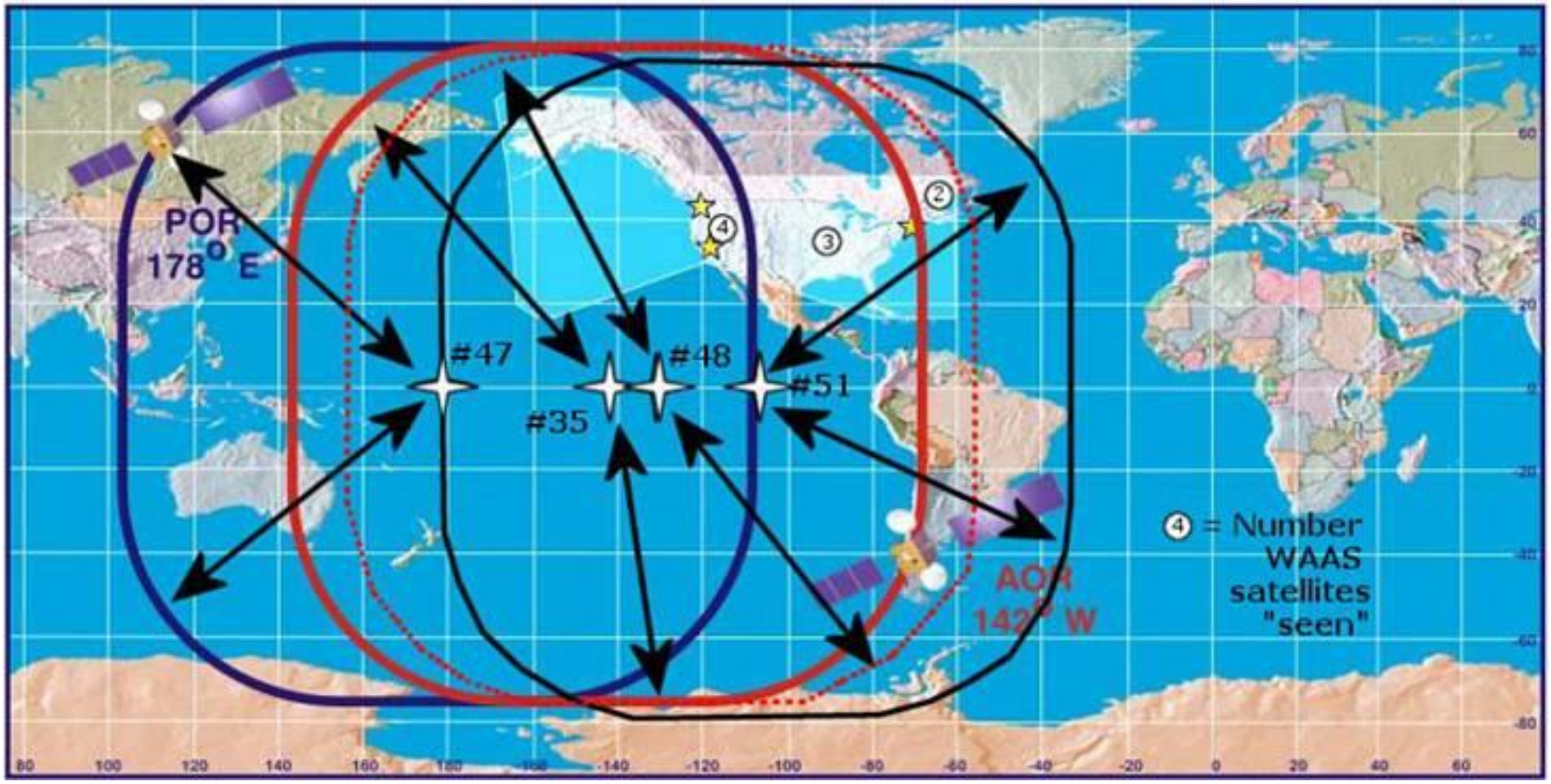


Station UNBC North 53° 53' West 122° 45' Height 770m Elevation cutoff 0° Obstacles 0%
Satellites 31 GPS 31 [Almanac.alm (6/24/2008)]

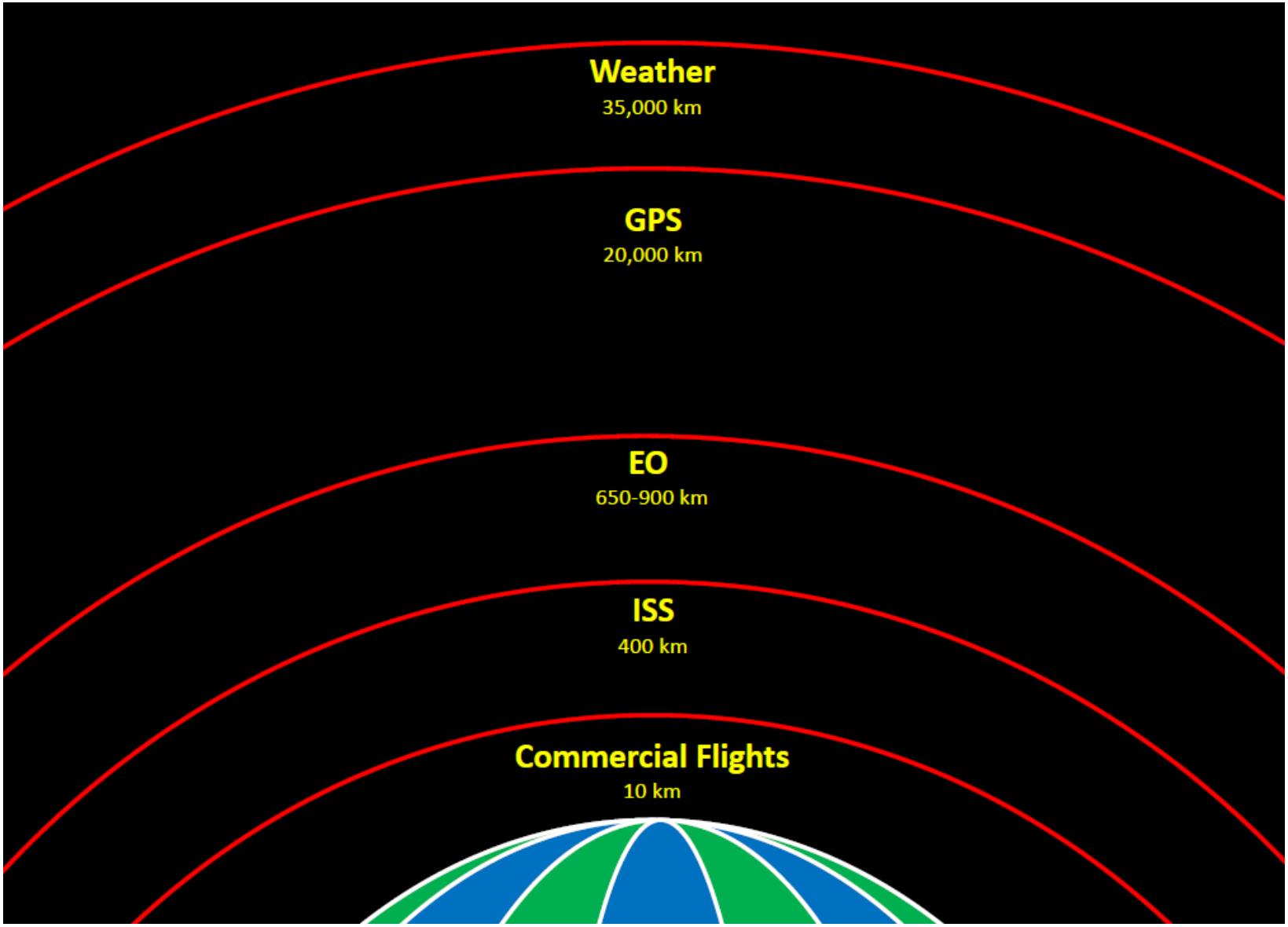
Time 11/16/2009 00:00 - 11/17/2009 00:00 (UTC-7.0h)

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*



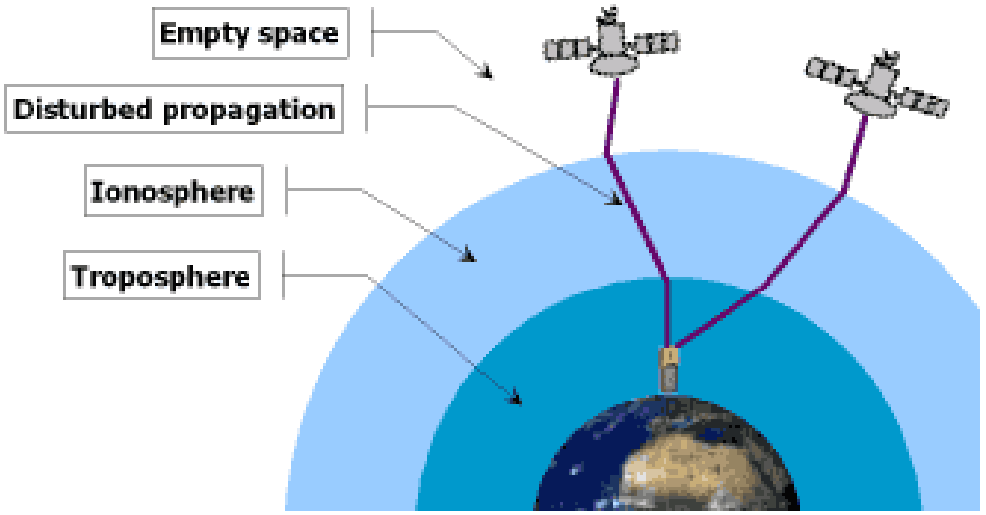
Earth from Space: Earth Observation (EO) satellites



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**



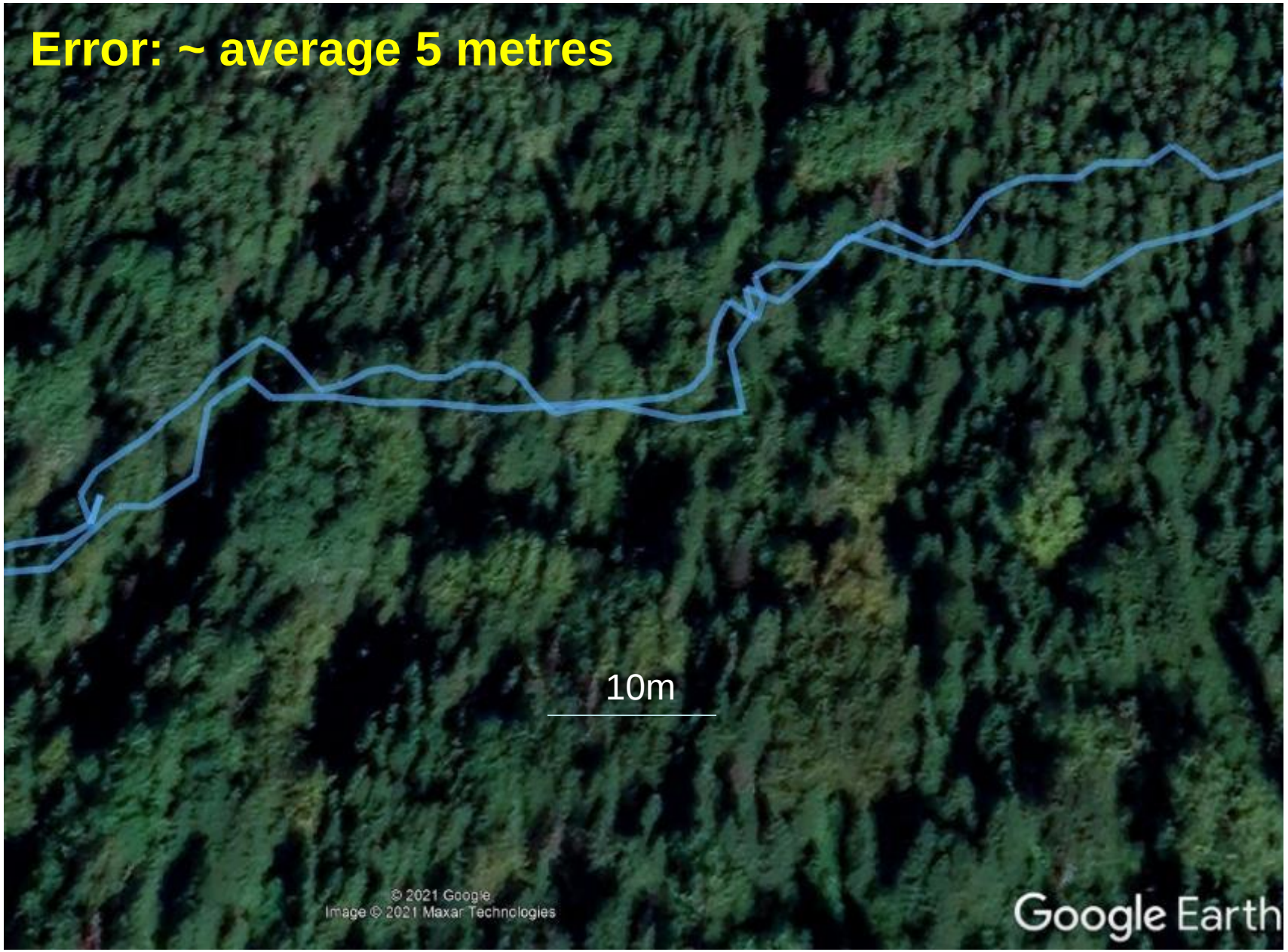
This is why your reading can change even when you don't move

We use DGPS to help remove these errors …

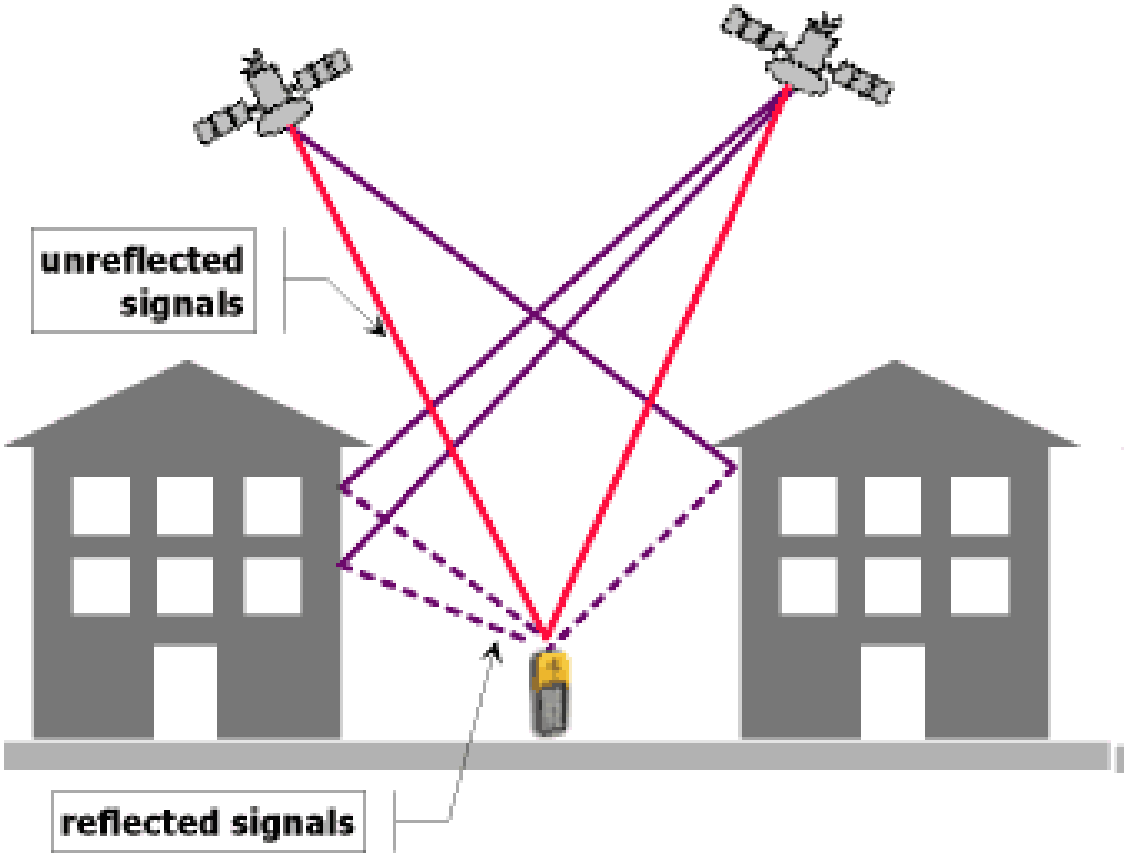
Uncorrected GPS ~10m
Corrected (DGPS) ~1m

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



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.

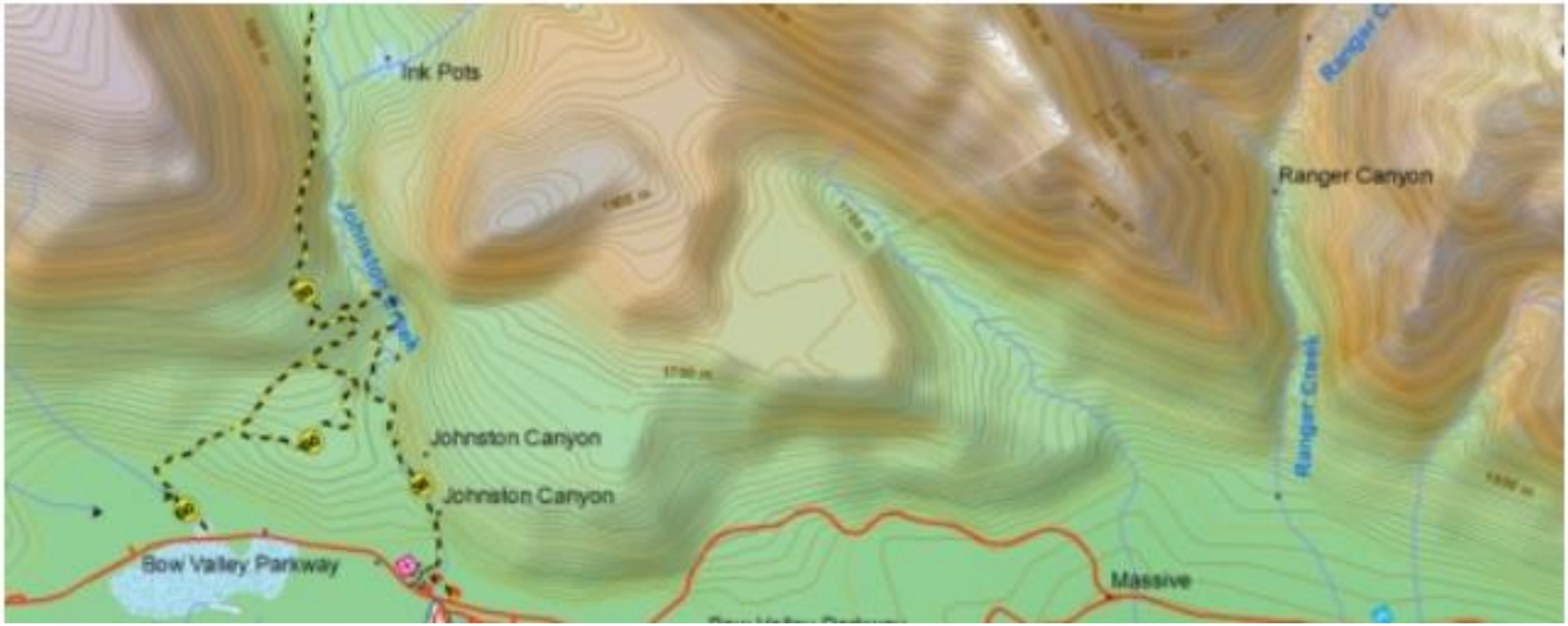
GPS Coordinates

Latitude: 51.24542307241623

Longitude: -115.83992958068848

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

Detailed Map



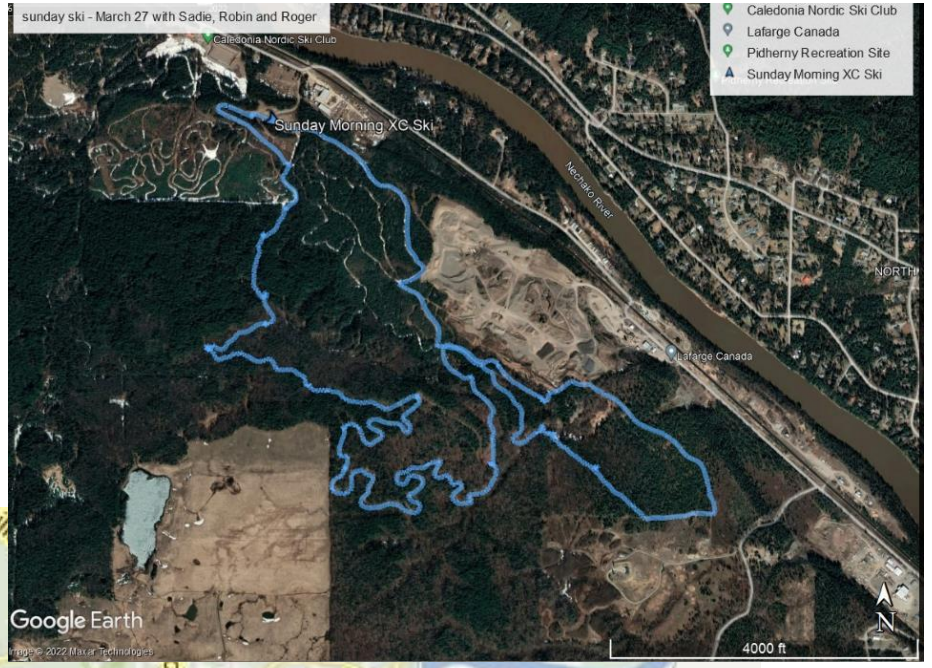
iPhone v handheld GPS**:** advantages: better maps/software, larger screen, cheaper
Advantages of handheld GPS: longer battery life, higher precision, more rugged

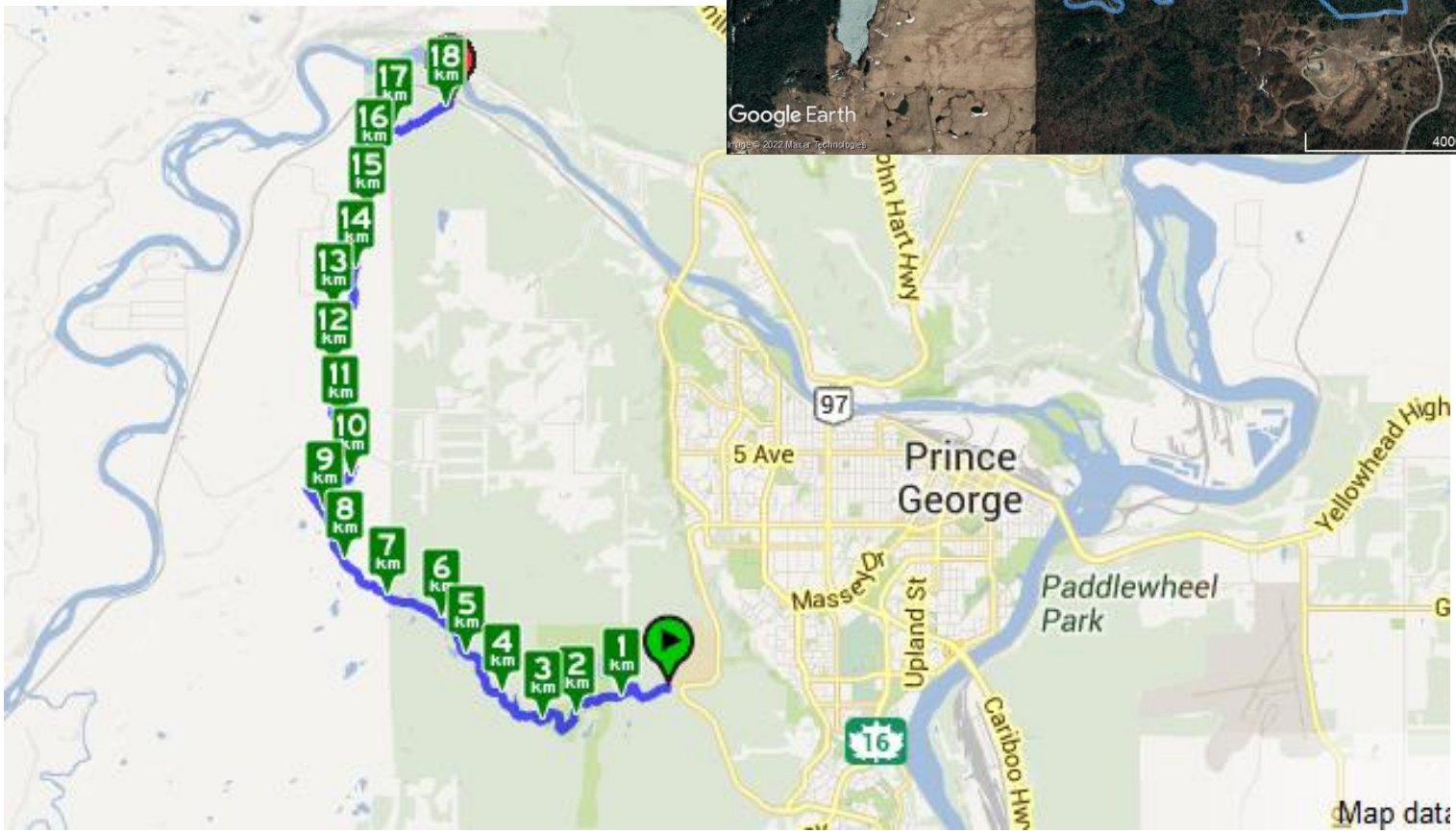
GPS data input:

http://openstreetmap.org

http://www.mapmyrun.com

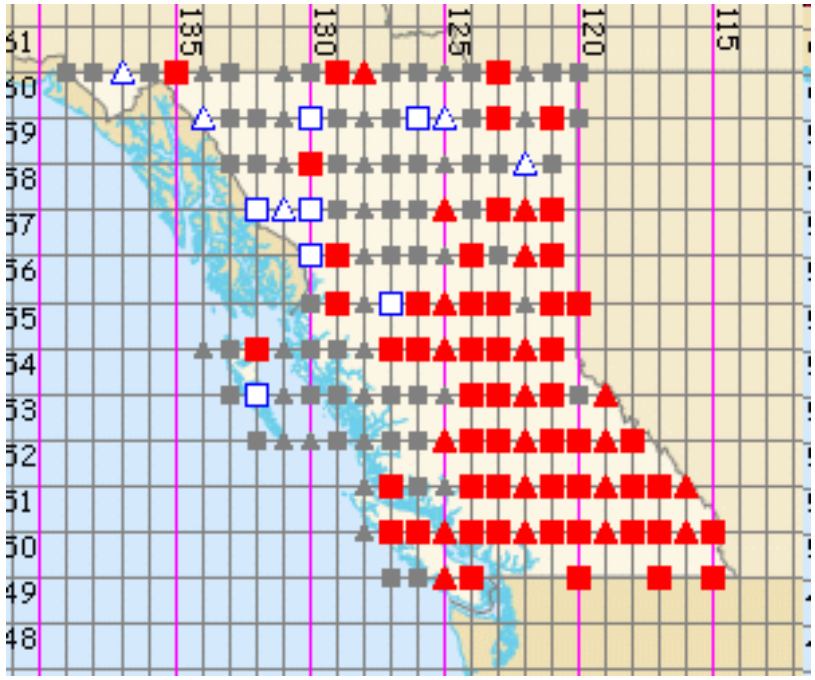
https://www.geocaching.com





Yasushi Takahashi traveled across Japan with a GPS to create a 7,163-km drawing to propose to his girlfriend. It's certified as World's largest GPS drawing.

‘結婚してください’



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