GNSS

&

Coordinate Systems

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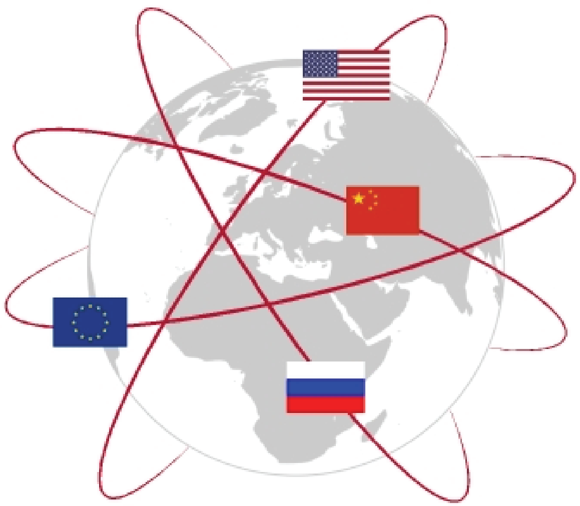
- GNSS
  - Encompasses all spaced spaced based satellite systems (i.e GPS, GLONASS, Galilleo, Compass/Beidou-2, etc).
- Focus on GPS (Global Positioning System)
  - Principles apply to all (in general)
- Designed to provide:
  - Autonomous Geo-Positioning
  - 3~10 m accuracy
  - Worldwide coverage
  - Available 24h per day
  - Low end user cost
  - Military Security



GNSS (Global Navigation Satellite Systems)

- More detail on expected accuracy (horizontal):
  - Instant horizontal positions to **an accuracy of 3-10 meters** (95% of the time) (easy) "pseudoranges"
  - Instant positions to **an accuracy of 1-2m** (differential *GPS)* (relatively easy, setup cost) : Based on "pseudoranges"
  - Post processed positions to **an accuracy of a few centimeters** (Kinematics *and Stop & Go)* (hard) "carrier phases"
  - Instant positions to **an accuracy of a few centimeters** (real-*time kinematics*, very hard) : Mainly by "carrier phases"

GNSS (Global Navigation Satellite System)

- More detail on expected accuracy (horizontal) (cont'd):
  - **[Professionals/Scientific]**
  - Post processed positions to **an accuracy of a few millimetres** over a few kilometres (very hard) by "carrier phase"
  - Post processed positions to **an accuracy of a few millimetres** over a few hundred kilometres (extremely hard) : by "carrier phase" (RTK in mm level is still very challenging!!!)
- Vertical 2-3x worse than horizontal (due to geometrical/atmospheric limitations)

GNSS Error Budget (1σ)

Error Source	Amount
Satellite Clock Error	~2.1m (res)
SV Ephemeris Error	0.05m (precise) to ~2m (broadcast)
Ionospheric Refraction	~4m (res. slant)
Tropospheric Refraction	~0.7m (res. slant)
Selective Availability (N/A)	~20m (turned OFF)
Receiver Noise	~0.5m
Multipath	~1.4m
Dilution of Precision (DOP)	~1-6 (lower the better)

Total Error is approximately 3~10m for a pseudorange based solution with basic error mitigation.

GNSS (Positioning Methods)

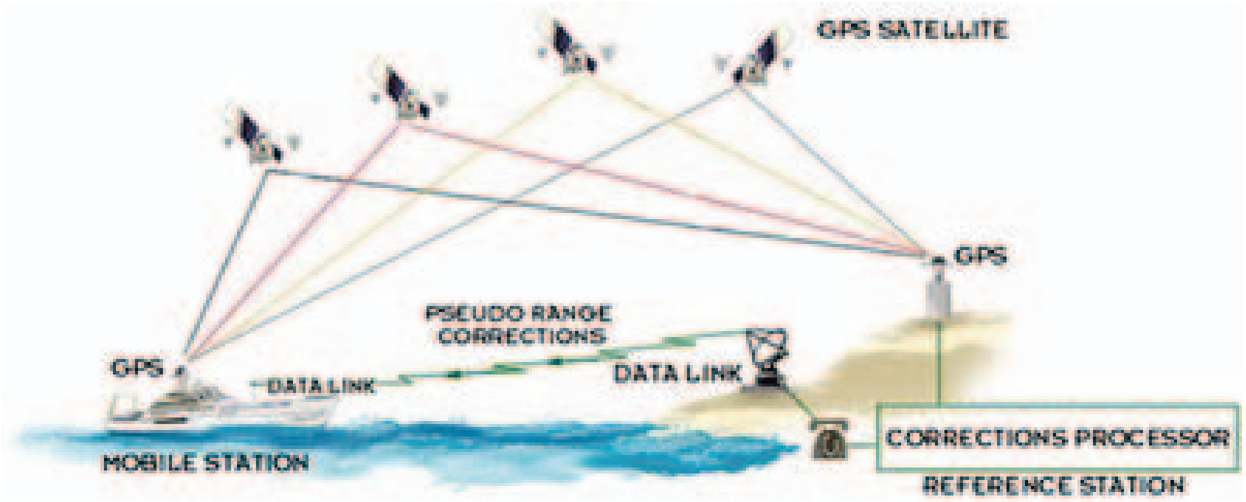
- Point Positioning (SPP)
  - Use of the C/A code pseudoranges
  - Single receiver
  - Standalone positioning
  - Accuracy: 3~10m (horizontal)
  - Land, Air, Marine Navigation

- Precise Point Positioning (PPP)
  - Use of carrier phase measurements
  - Requires use of dual frequency receiver (L1&L2)
  - Post-Processed (precise ephemerides)
  - Accuracy: <cm level (depends on environment/methodology)

GNSS (Positioning Methods)

Relative Positioning

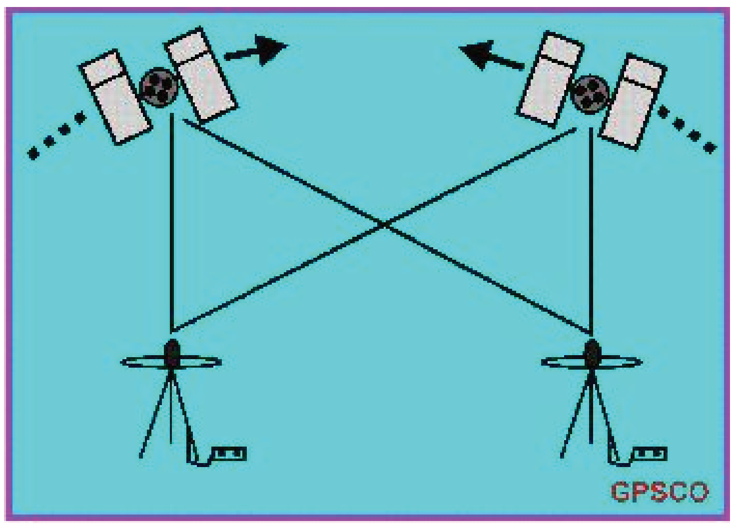
- Code Based DGPS (Differential GPS)
  - Reference + Rover + Communication Link
  - Accuracy: ~1-2m
  - i.e. WAAS



Relative Positioning (cont'd)

Carrier Phase Based

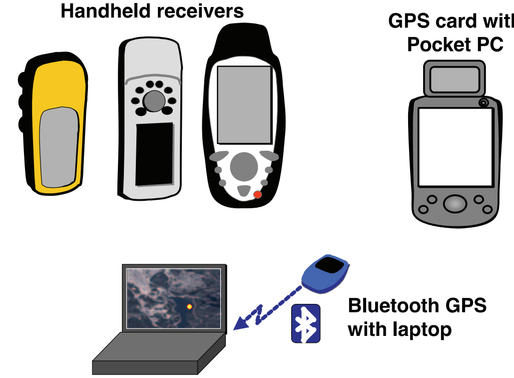
- Real Time or Post processed
- 2 Receivers + Reference + Computer + Software
- Accuracy: ~2cm over 80km (real-time)
- Accuracy: 5mm +/- 1ppm*baseline (post-processed with geodetic grade software)



- Dx,dy,dz is the solution
- Must know position of reference point for absolute coordinates

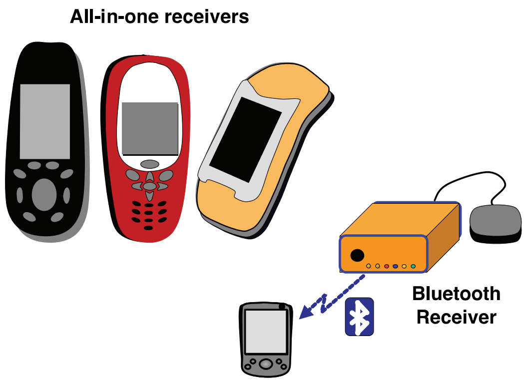
GNSS (Receiver Categories)

- Recreational ($200-$600)
  - Low end single frequency receiver (L1)
    - Code based measurements only
  - Handheld (antenna, receiver, controller integrated)
    - Garmin, Magellin, Smartphone
  - Intended Use:
    - Marking waypoints, tracks, routes (navigation info)
  - No Access to raw data, only position solution.
  - Most are WAAS enabled.
  - Metre level + accuracy



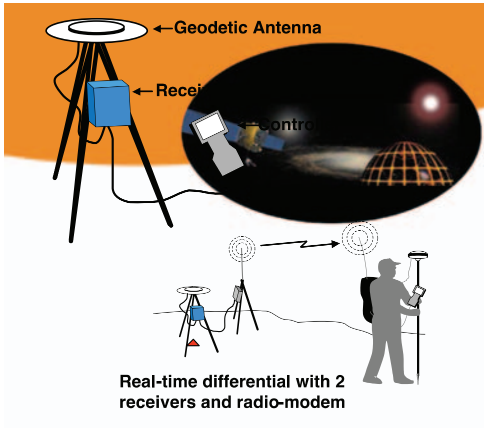
GNSS (Receiver Categories)

- Mapping ($2000 - $10,000)
  - Higher end single frequency receiver (L1)
  - All in one or separate
  - Can log position into GIS software
  - Can record raw data (Code+Phase) for post-processing.
  - Expected Accuracy:
    - ✓ Depend on Methodology + Observable (code/phase)
    - ✓ Metre Level down to 10 cm level.



GNSS (Receiver Categories)

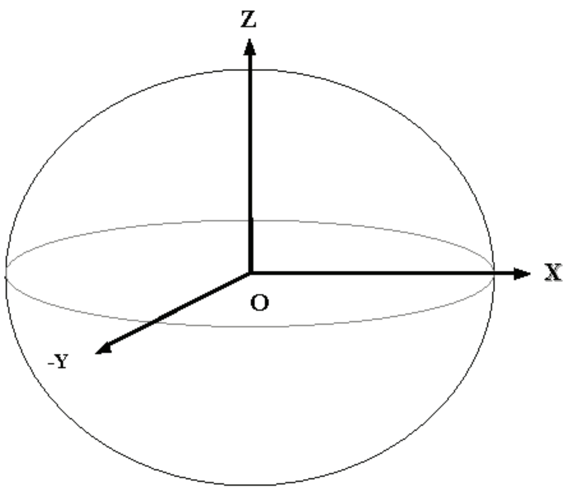
- Geodetic (>$10,000)
  - Dual Frequency Receiver (L1/L2)
  - Receiver/Antenna/Controller
    - ✓ Separate components
    - ✓ Geodetic antenna ($2000-$10,000)
  - Intended use is for sub-cm to cm level accuracy
    - ✓ Can record raw (code+phase) dual frequency observations
    - ✓ Capable of real-time kinematic (with carrier phases – cm level)



GNSS (Coordinate Systems)

- Coordinate Systems
  - A set of rules that specify how the coordinates are to be assigned to the points.
  - i.e. 2D rectangular Cartesian Cartesian Coordinate System
- Reference Coordinate System
  - Origin is defined and the orientation of the axis.
  - i.e Centre of mass of the Earth + z-axis parallel to spin axis of Earth + x-axis intersects Greenwich Meridian (CTS).
  - Define various physical constants, conventions, etc.
- Geodetic Datum
  - Addition of ellipsoid of revolution to approximate Earth's surface.

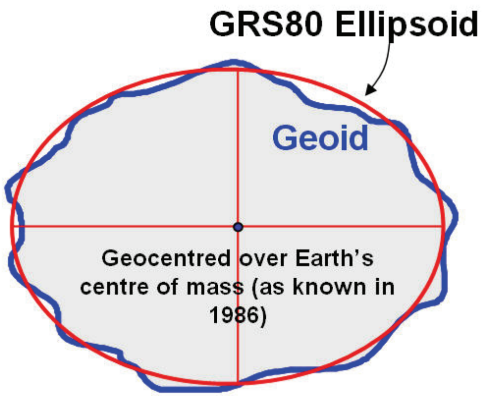
GNSS (Coordinate Systems)



- Realization
  - Coordinate system is realized by assigning numerical values to tangible points (very accurate observations/computations $$).
  - Usually done for a select few points with the highest accuracy.
    - ✓ These points serve a basis for subsequent surveys to be connected to

Coordinate Systems

- ITRS
  - International Terrestrial Reference Frame
  - Various realizations: ITRF1996….ITRF2005, ITRF2008 (IGS08)
- WGS84
  - Coordinate system of GPS. WGS84(G1150).
  - Only have access to this system through the broadcast orbits
  - Aligned with the ITRS (and its ITRF realizations) in 1994. No official transformation, 10cm level.
- NAD83(CSRS)
  - Current realization of NAD83
  - Connected to the ITRF1996 EPOCH:1997.
  - Offset from geocentre by ~2m

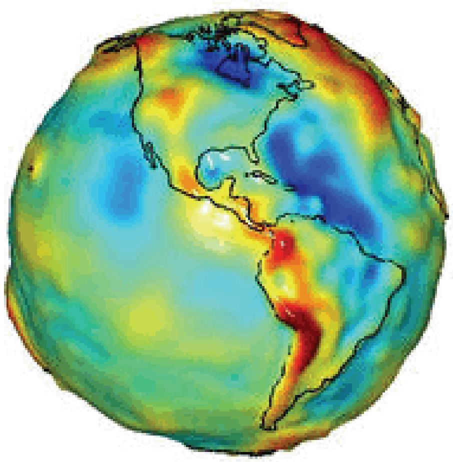


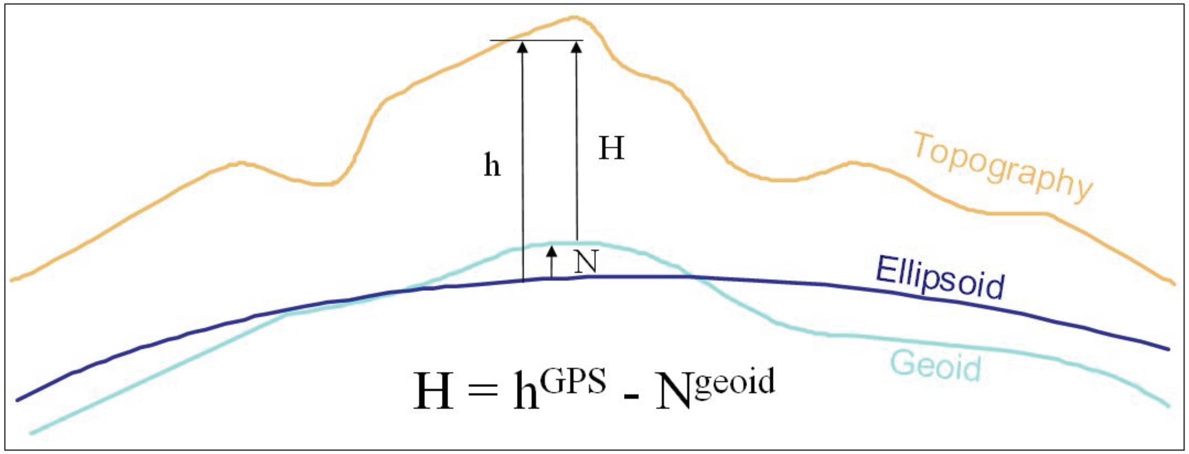
GNSS (Datums)

- GPS
  - Broadcast datum is WGS84
  - Handheld units will display in WGS84 (current realization).
    - ✓ Even if you select NAD83 in the unit – you may still be in WGS84.
    - ✓ Manufactures use a 3 parameter datum shift
    - ✓ "NIMA 8350.2" published by NGA (National Geospatial Agency)
    - ✓ Specification states dx:0+/-2m, 0+/-2m, 0+/-2m.
    - ✓ In reality: no good way to know what the manufacturers are doing.
  - To get positions in NAD83(CSRS)
    - ✓ PPP (NRCan or GAPS+ITRF transformation to NAD83(CSRS))
    - ✓ Post Processed Relative Positioning (ITRF -> NAD83(CSRS))
    - ✓ TRNSOBS - http://www.geod.nrcan.gc.ca/apps/trnobs/trnobs_e.php
    - ✓ Coast Guard Beacon Corrections (Code based DGPS)

GNSS (Vertical Datums)

- GPS
  - Solution is given in geodetic coordinates (lat, long, h)
  - h is the ellipsoidal height, mathematical value.
  - Must transform from ellipsoidal height to orthometric height.
  - Orthometric height referenced to the geoid (best approx. of mean sea level)
  - This process adds several **centimetres** of uncertainty to the final transformed height.





GNSS (Vertical Datums)

- NRCan Recommendation:
  - Most Precise (proper water management at the highest precision)
    - ✓ Get the best possible ellipsoidal heights from GPS.
    - ✓ Apply the CGG2010 geoid model to get orthometric heights.
  - If the survey must conform with the published elevation(s) of (a) specific nearby benchmark(s) or tide gauge(s),
    - ✓ Do additional GPS at benchmark(s) or tide gauge(s) and apply the CGG2010 geoid model to produce orthometric heights. Determine the difference (or bias) between orthometric and published elevations (should be constant within a small area).
    - ✓ Apply this bias to your orthometric heights.

- Quicker (but less accurate over a large area)
  - ✓ To conform with the overall CGVD28 levelling network
  - ✓ Get the best possible ellipsoidal heights from GPS
  - ✓ Apply the HTv2.0 Height Transformation
    - o Uses CGG2000 that has been constrained to the CGVD28 datum

HTv2.0 Transformation

- http://www.geod.nrcan.gc.ca/apps/gpsh/gpsh_e.ph
- Must use standalone version of application to apply CGG2010. Can get this from NRCan.

Summary

Accuracy Rule of Thumb

Observable Type	Accuracy
Pseudo-range	Metre Level +
Carrier Phase	cm level

Difficulty:

Accuracy Level	Difficulty / Cost
Metre +	Easy/Least Expensive (i.e. iPhone)
Centimetre	More Difficult = More Work = $$$$

*As we improve our accuracy, we increase our costs and effort

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