Tutorials and Processing of GPS Survey Data

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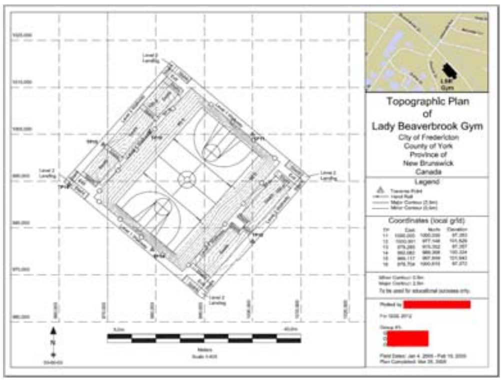
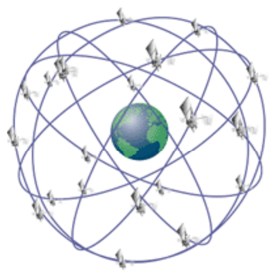




Tutorials of GPS Survey

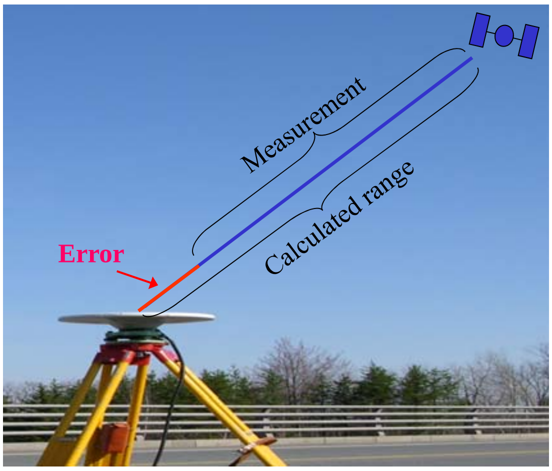
◆ *Contents*

- **Orbits (precise or broadcast)**
- **Data rate and observation span**
- **Elevation angle**
- **Points to be observed on your lab.**
- **Processing software and methodology**
- **Processing GPS data**
- **Appendix: WGS84 System, GPS Height**

Tutorials of GPS Survey

Recording GPS observation

- GPS measures ranges.
- If a reference station is on a known location then the range can be calculated.
- The difference between the measured and calculated ranges is measurement error.
- The error measured at a reference station is similar to the error measured by nearby receivers (→ differential approach)



Tutorials of GPS Survey

GPS Orbits

1. **Broadcast orbit from GPS satellites *(Real-Time Processing)***

2. **IGS Products *(In Near Real-Time Processing)***

The IGS (international GNSS service) collects, archives, and distributes GPS and GLONASS observation data sets of sufficient accuracy to meet the objectives of a wide range of scientific and engineering applications and studies. These data sets are analyzed and combined to form the IGS products.

IGS products support scientific activities such as improving and extending the International Terrestrial Reference Frame (ITRF) maintained by the International Earth Rotation and Reference Systems Service (IERS), monitoring deformations of the solid Earth and variations in the liquid Earth (sea level, ice sheets, etc.) and in Earth rotation, determining orbits of scientific satellites, and monitoring the troposphere and ionosphere.

(http://igscb.jpl.nasa.gov/components/prods.html) IGS: SOPAC, CDDIS, IGN, KASI – US, France, and Korea

Tutorials of GPS Survey

◆ *GPS Orbits (in 2009)*

IGS Product Table [GPS Broadcast values included for comparison]		Accuracy	Latency	Updates	Sample Interval	Archive locations
GPS Satellite Ephemerides/ Satellite & Station Clocks						
Broadcast	orbits	~160 cm	real time	--	daily	CDDIS(US-MD) SOPAC(US-CA) IGN(FR)
	Sat. clocks	~7 ns				
Ultra-Rapid (predicted half)	orbits	~10 cm	real time	four times daily	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. clocks	~5 ns				
Ultra-Rapid (observed half)	orbits	<5 cm	3 hours	four times daily	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. clocks	~0.2 ns				
Rapid	orbits	<5 cm	17 hours	daily	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. & Stn. clocks	0.1 ns			5 min	
Final	orbits	<5 cm	~13 days	weekly	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. & Stn. clocks	<0.1 ns			5 min	

(accessed on 21 March 2009)

Note: These values are differences from SLR measurements. Also, even if there is an errors, it can be minimized by differential techniques on GPS processing.

Tutorials of GPS Survey

◆ *GPS Orbits (in 2010, 2011)*

IGS Product Table [GPS Broadcast values included for comparison] – updated for 2009!		Accuracy	Latency	Updates	Sample Interval	Archive locations
GPS Satellite Ephemerides/ Satellite & Station Clocks						
Broadcast	orbits	~100 cm	real time	--	daily	CDDIS(US-MD) SOPAC(US-CA) IGN(FR)
	Sat. clocks	~5 ns RMS ~2.5 ns SDev				
Ultra-Rapid (predicted half)	orbits	~5 cm	real time	at 03, 09, 15, 21 UTC	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. clocks	~3 ns RMS ~1.5 ns SDev				
Ultra-Rapid (observed half)	orbits	~3 cm	3 - 9 hours	at 03, 09, 15, 21 UTC	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. clocks	~150 ps RMS ~50 ps SDev				
Rapid	orbits	~2.5 cm	17 - 41 hours	at 17 UTC daily	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. & Stn. clocks	~75 ps RMS ~25 ps SDev			5 min	
Final	orbits	~2.5 cm	12 - 18 days	every Thursday	15 min	CDDIS(US-MD) IGS CB(US-CA) SOPAC(US-CA) IGN(FR) KASI (KOREA)
	Sat. & Stn. clocks	~75 ps RMS ~20 ps SDev			Sat.: 30s Stn.: 5 min	

Note: Compared these with last year,

1) All orbits are dramatically improved.

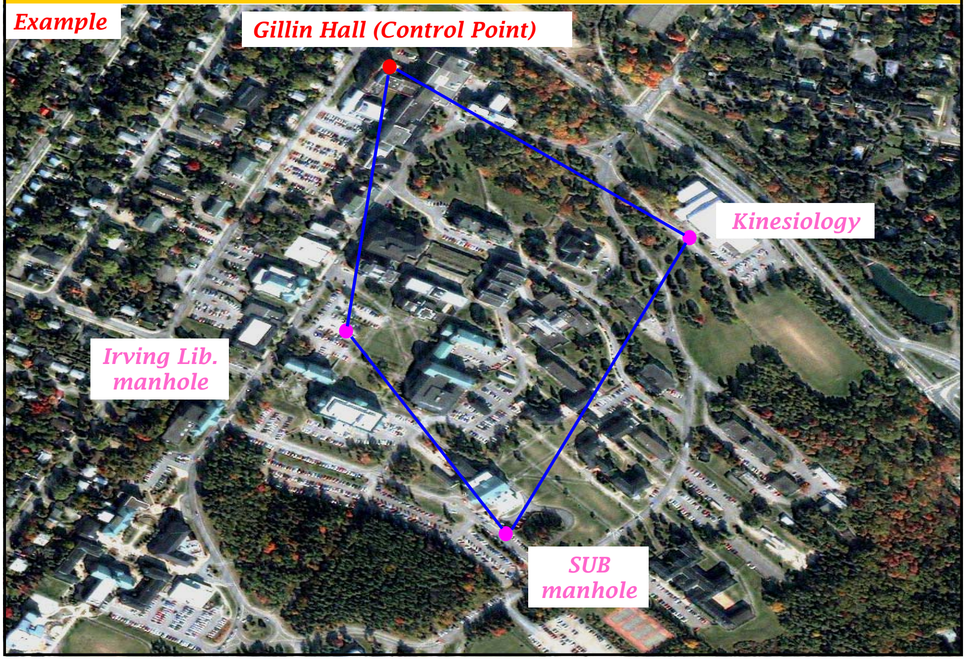
2) Clock errors are also improved.

3) The improvements are very beneficial in "precise point positioning".

4) In your field survey designed, the broadcast, ultra-rapid or rapid orbit is fine.

(accessed on 22 March 2010 & 22 March 2011)

Tutorials of GPS Survey



Tutorials of GPS Survey

◆ *Data Rates and Minimum Obs. Time*

· **More data means more redundancy → at least 5 seconds data rate would be recommended. Normal value for the data rate is 30 seconds because of the storage issues, and it depends on the observation time.**

· **Minimum observation time? at least 30min, 45min**

-- Hint: In principle, the position can be determined with one epoch in terms of "least square adjustment". We are dealing with carrier phases (+code). There is unknown value on the equation, called integer ambiguity, which may need to be determined during the process.

· **Masking angle? 5 deg. (not suggested over 10 deg.)**

Tutorials of GPS Survey

◆ *GPS Processing Software:*

[Geodetic Software – post mission, examples]

: **Bernese GPS Software** (from AIUB – Astronomical Institute of University of Bern, Bern, Switzerland, Available for our GGE department, academic & commercial)

: GIPSY-OASIS II (from NASA JPL, free)

: GAMIT (from MIT), **DIPOP** (from UNB, free)

[Commercial Software– post mission mostly, examples]

: ***TGO™ (Trimble Geomatics Office)***

: TTC™ (Trimble Total Control), Topcon Tools, Leica Geosystem's Ski Pro

: GrafNav™ (from NovAtel Inc., Calgary)

: MultiRef™, FlyKin™ (from Geomatics Eng. at U of Calgary)

: UNB-RTK (from GGE), Precise Point Positioning (free software, NRCan (Canada), Auto-GIPSY (NASA, ~free), UNB-GAPS (UNB, free)) etc.

Tutorials of GPS Survey

◆ *GPS Processing Methodology*

[Measurements from a GPS Rx, Trimble, Leica, or TOPCon receiver]

: C/A Code, L1 phase, (+ L2 phase, P2 code)

1. **Short baseline case – same atmosphere (at UNB campus)**

: C/A and *L1* code/carrier phase measurements

: **Never use the L1 and L2 combination**, e.g. ionosphere-free linear combination due to the amplification of the noise.

: GGE2012 practice.

2. Longer baseline case – different atmosphere (over 10 km)

: Either **C/A + *L1*** phase with the method of atmospheric error mitigation, or **C/A + both *L1 and L2*** phase combination to mitigate errors mainly by the ionosphere. Frequently, this combination is referred to as "ionosphere-free combination": GGE2013 practice.

Processing GPS Data

◆ GPS Processing Introduction: TGO™

: Post mission

: Solutions are too optimistic (only mathematical correlation is considered)

: Limited analysis

: Commercial software can hardly guarantee the accuracy of less than cm from the true value in static mode. In a real-time mode or RTK mode, the achievable accuracy is lower. You must be very careful for this.

: For those who works for map-matching, land property management, or low-precision GIS which don't need a high-precision application

: For those who study for geodetic accuracy, please use other geodetic software stated before.

Processing GPS Data

◆ GPS Recording in Field:

: One Zephyr/Zephyr Geodetic Antenna

: One Trimble 5700 Rx

: One TSCe™ Controller

: One Triback

: One Tripod

: Cables (Coaxial to Rx, BNC type, Controller)

Processing GPS Data

◆ *GPS Data Preparation:*

: Not general scheme, only for Trimble Rx and Software related

*: Download the *.dc controller files from controller using RS232 port (please see the diagram below)*

Connecting Cable from TSCe to Computer's COM port (or USB port)

Processing GPS Data

◆ *GPS Data Preparation: Two Options*

1. *From TSCe Controller, you can download *.dc file and *.dat. They can be processed in TGO software*

2. *Secondly, you can download raw data from flash card in the receiver. These data sets should be converted to the standard form. (preferred)*

Processing GPS Data

◆ *GPS Data Preparation:*

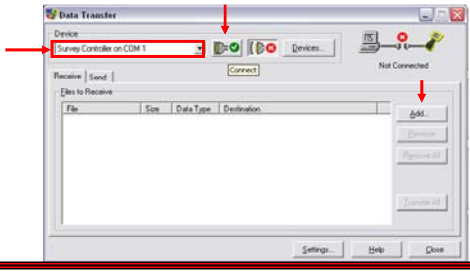
: Once the cables are connected, then please launch the program, "Data Transfer"

: You also have to set up the PC communication in the TSCe controller to connect each other (between TSCe and Computer)

: If TSCe is ready to be connected, please choose the proper device and click the connection button (see below)

: Once succeeded, you must add the file and then choose transfer all

*: *.dc file and *.dat will be downloaded.*



Processing GPS Data

◆ *GPS Data Preparation:*

: Another way to download the GPS data is from the CF (compact flash) memory card directly.

: I prefer to this way as we don't need to be dependent of a controller. Also, it will minimize your mistake of the controller settings. Strange thing I've found is that once the controller is close earlier or once you failed to end the survey on the controller, the download data from the controller had a problem. It failed to be downloaded all spans.

: Please follow this way at least for the Trimble Rx and TSCe controller for our GPS lab.

*→ Download the raw data (in *.T01 format) from CF memory card*

→ Transfer from the raw format (.T01) to *.dat with the following program:* ***runpkr00.exe***

Processing GPS Data

◆ *GPS Data Preparation:*

*: Download the program, called "**R-Utilities**" from*

http://facility.unavco.org/software/download_transfer/trimble/trimble.html

: use the following sentence to decode the *.t01 file

***: runpkr00 -d -tt01** file_name.t01 file_name.dat*

(You may also download the program from the course Blackboard. Please try to find the program yourself first.)

accessed on 21 March, 2011)

Processing GPS Data

◆ *Important Setup for TGO™:*

1. Please find the attached the file (Current.csd) ***in Blackboard*** which you are going to use to ***set up NB Double Stereographic Projection with NAD83 CSRS datum***. You should copy this file to the following directory or the corresponding directory TGO is installed.

    c:\Program files\Common files\Trimble\Geodata

2. After you copy it, go to TGO and follow the below instructions:

File → Project Properties → Coordinate System →

Coordinate System Settings → Change →

Coordinate System and Zone (→ Canada and Plane Rectangular) →

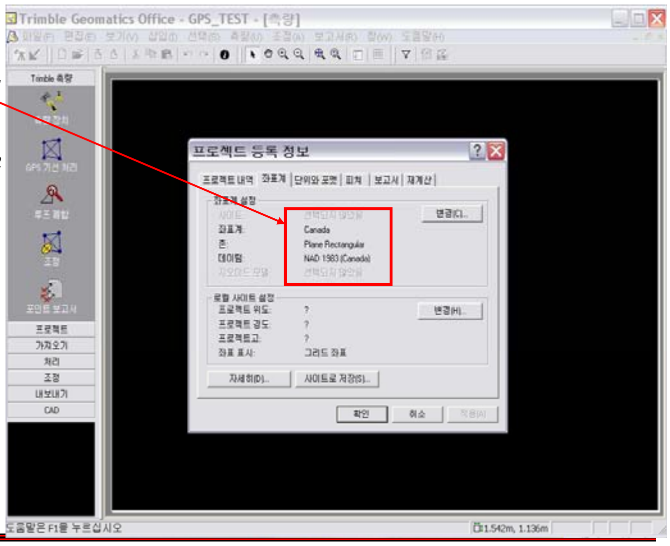
No Geoid Model → Finish → Apply

Processing GPS Data

You must see the following on the project properties.

If different, please see previous file and find out the problem.

If this is different, your entire project for GGE2012 and GGE2013 will be wrong.



Processing GPS Data

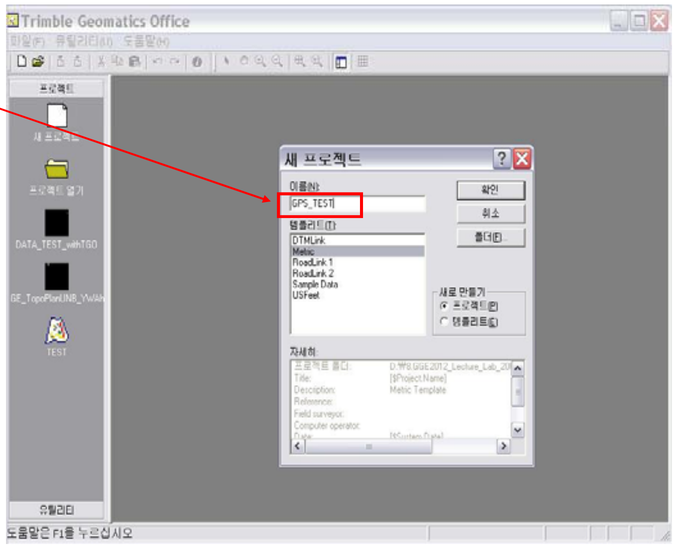
Go to

File→ New

→ make project name

(should be metric system)

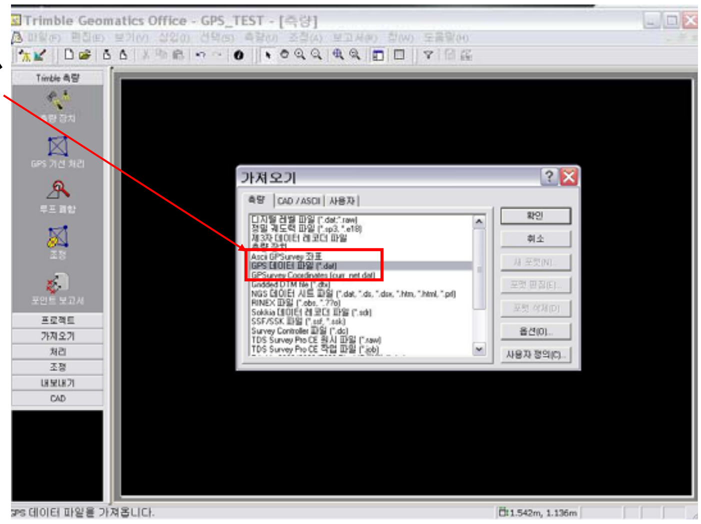
→ OK



Processing GPS Data

Go to

File→ Import → GPS data file (.dat)*



Processing GPS Data

You may see the following file lists on DAT check-in. Most important parts are the antenna height, antenna types, and reference points of antenna (either "bottom of notch, top of notch, or antenna phase center for each antenna which you used). ***You "HAVE TO" input the corresponding values on each field "EXACTLY". Most important !!!***

DAT 체크인

	사용	이름	파일 이름	시작 시간	정지 시간	수신기 종류	수신기 S/N	안테나 높이	안테나 종류	높이 지점	피처 코드
1	☑	stu1	06781191.dat	12:45:47 29 4 2007	15:04:47 29 4 2007	5700	440100678	1.492m	Zephyr Geodetic	Bottom of notch	
2	☑	path	06781192.dat	15:19:17 29 4 2007	16:41:17 29 4 2007	5700	440100678	1.437m	Zephyr Geodetic	Bottom of notch	
3	☑	oromocto	06781193.dat	17:06:47 29 4 2007	17:58:17 29 4 2007	5700	440100678	1.526m	Zephyr Geodetic	Bottom of notch	
4	☑	1	06781201.dat	10:12:55 30 4 2007	10:51:23 30 4 2007	5700	440100678	0.115m	Zephyr	안테나 페이즈 센터	
5	☑	for	26191190.dat	13:23:17 29 4 2007	13:58:47 29 4 2007	5700	440102619	0.170m	Zephyr Geodetic	Bottom of notch	
6	☑	chapman	26191191.dat	14:32:17 29 4 2007	14:57:17 29 4 2007	5700	440102619	1.531m	Zephyr Geodetic	Bottom of notch	
7	☑	lot	26191192.dat	16:15:17 29 4 2007	18:16:17 29 4 2007	5700	440102619	1.518m	Zephyr Geodetic	Bottom of notch	

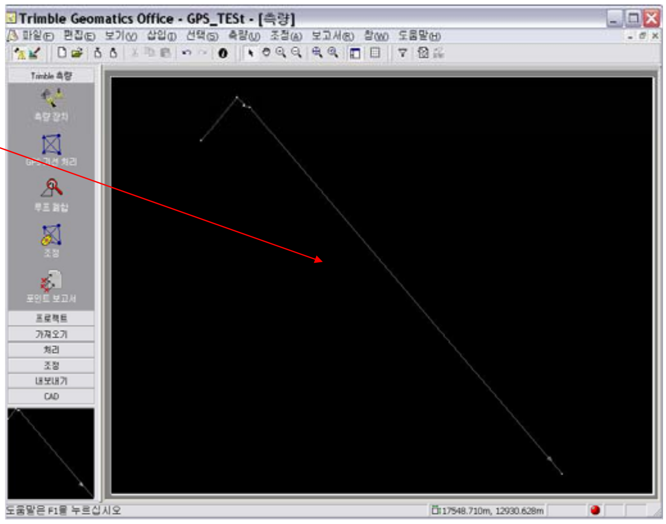
This includes: Antenna Height, Antenna Type, and Antenna Reference Point (Always use the Phase Center and input your "hand-calculated" phase center value for your antenna for exercise!!!

확인 취소 리셋

Processing GPS Data

Now, you will see the corresponding network diagram for your GPS observations

(Left is just an example from GGE2013 survey practicum II)

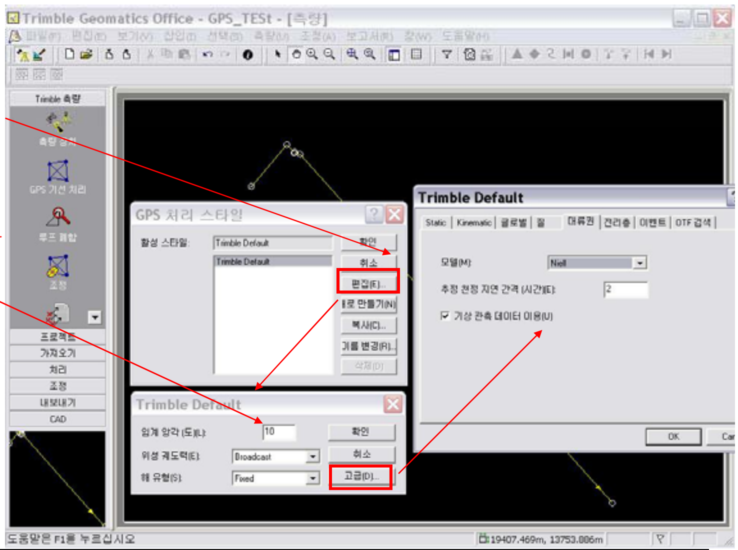


Processing GPS Data

Go to Surveying → GPS Baseline Processing Style

Edit *→ Select mask angle to 5 deg. → Orbit (Either broadcast or precise) → Fixed type solution*

Advanced *→ please see the details of each tab.*

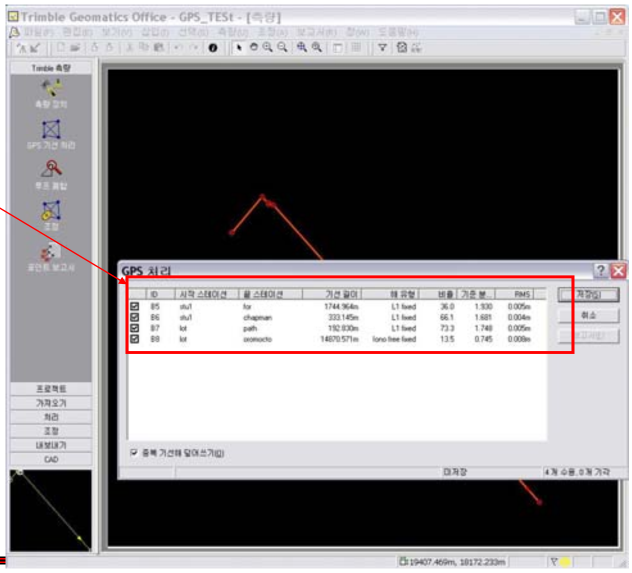


Processing GPS Data

Go to Surveying → GPS Baseline Processing (F9): it will process your "selected" baselines.

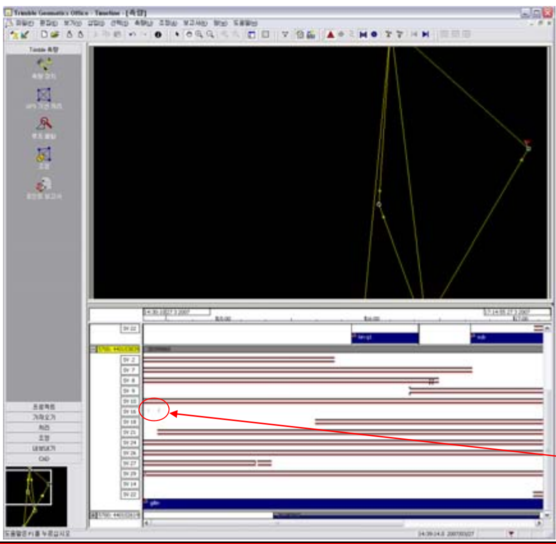
After finished, you will see the similar result like the left.

Please save the file and see all the details from the saved file.



Processing GPS Data

◆ Cycle Slip Manipulation



*: Make a project and copy all *.dat to checkin directory.*

: View → Timeline

(check the time line and then decide if there're any data to remove or not to be processed, minor!)

: Cycle slip elimination (check the jumps and deactivate those)

Processing GPS Data

◆ *GPS Network Adjustment: Fixed Control Point*

: Bring all GPS data

: Check the antenna height or put the correct APC of the antenna

: Click Process button (will take time)

: Baselines can be seen (as white line) in TGO™

: Adjustment will be done by selecting the baselines that make a triangle network

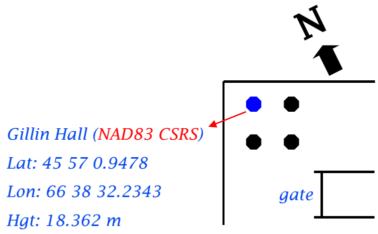
: Selected and then click the Adjust button

: Report → Network Adjustment Report

: Analysis the results

Note: Fixed Point (Gillin Hall): From GPS Lab.

(Applied to TGO and adjusted based on this)

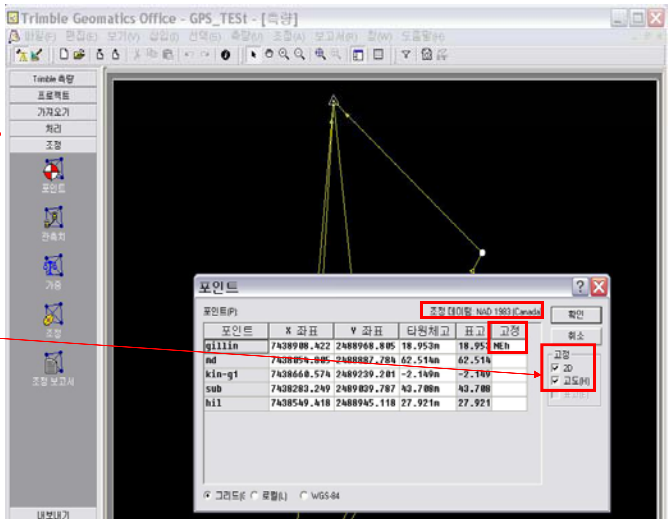


Processing GPS Data

After processed the baseline successfully, go to Adjustment. Check Adjust to NAD 1983 (Canada)

Adjustment → Points → you must ***fix*** *"Gillen Hall" with the coordinates provided.*

Adjustment → Adjustment (F10)



Processing GPS Data

After the adjustment, you can find the final adjusted coordinates from the “adjustment report”.

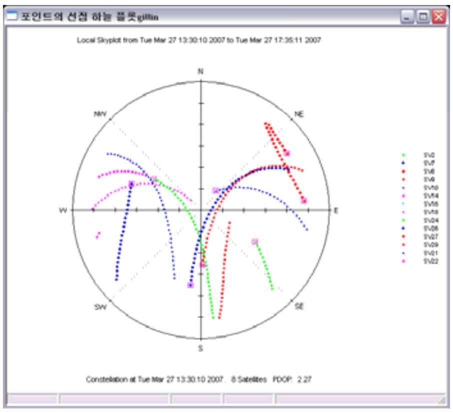
From the report, your final horizontal coordinates will be one like below. You have to make it sure whether Gillin Hall is correctly fixed or not.

Adjusted Coordinates

point name	Lat.	N Err	Long.	E Err	Ell.Hgt.	H Error	Fixed
md	45°56'33.29392"N	0.003m	66°38'35.92491"W	0.002m	62.514m	0.006m	
kin-g1	45°56'52.93538"N	0.008m	66°38'19.65835"W	0.004m	-2.149m	0.010m	
gillin	45°57'00.94780"N	0.000m	66°38'32.23430"W	0.000m	18.953m	0.000m	위도 경도 h
sub	45°56'40.70220"N	0.002m	66°38'28.88653"W	0.002m	43.708m	0.006m	
hil	45°56'49.31809"N	0.003m	66°38'33.30424"W	0.003m	27.921m	0.008m	

These heights are the ellipsoidal ones: You have to change them to the orthometric height.

Processing GPS Data: Review



[Check]

: SkyPlot

: Survey Plan

: DOP Check

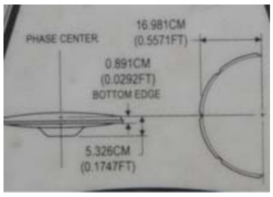
(must be pre-determined)

Processing GPS Data: Review

◆ *Antenna Height (Pl. use APC)*

: Please calculate antenna phase center (APC) values provided on the back of the antenna.

: Zephyr Geodetic™ Antenna

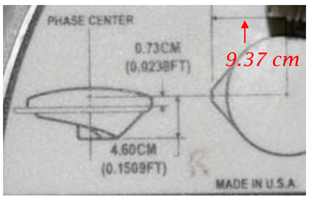


Processing GPS Data: Review

◆ *Antenna Height (Pl. use APC)*

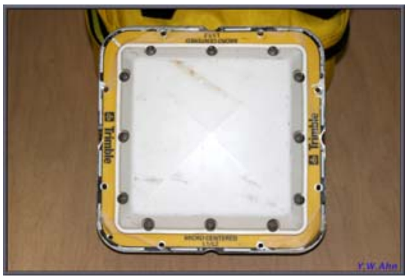
: Please calculate antenna phase center (APC) values provided on the back of the antenna.

: Zephyr Antenna



Processing GPS Data: Review

◆ *Antenna Height (Pl. use APC)*



: Please calculate antenna phase center (APC) values provided on the back of the antenna.

: Micro Centered L1/L2

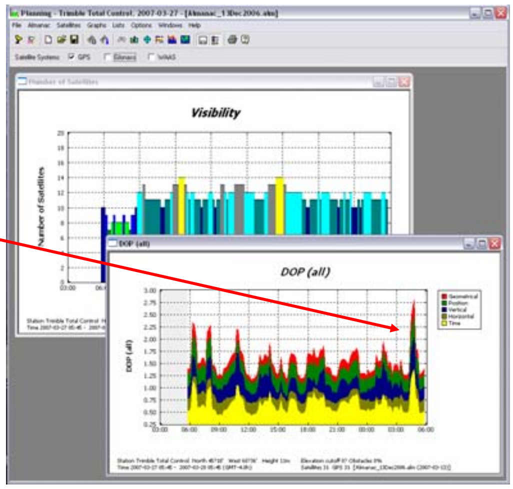
Processing GPS Data: Review

◆ *TIP: Concerned about geometry and visibility?*

*: Please use the "**Planning**" Tool before you start surveying!*

: Can you find any bad time for your survey schedule from the right figure?

: You can check them in any time and any location in the world if you provide the proper almanac to the software (it's in the TGO utilities!)



Processing GPS Data: Review

◆ *TIP: Need a pre-analysis in detail?*

*: Please use **TEQC** quality check program provided by UNAVCO*

: You can download it from the link

http://facility.unavco.org/software/teqc/teqc.html

: It can manipulate, concatenate, pre-analyze, pre-processing GPS, GLONASS, SBAS

References

[1] Leick, A., 1995, "GPS Satellite Surveying", 2nd Ed. John Wiley & Sons, New York.

[2] NRCan, http://www.geod.nrcan.gc.ca/tools-outils/gpsh_e.php

[3] SNB, http://www.snb.ca/, Service of New Brunswick.

[4] Lecture Note GGE2012, 2007, by Prof. Peter Dare.

[5] Hofmann-Wellenhof. B., H. Lichtenegger and J. Collins, 1998, "GPS Theory and Practice". 4th Ed., Springer-Verlag, New York.

[6] Kavanagh, 2006, "Surveying: Principles and Application", 6th Ed. New Jersey, Prentice Hall.

WGS84 System

Earth-Centered Earth-Fixed (ECEF) Coordinate System

- For the purpose of computing the position of a GPS Receiver
  - Rotate with the Earth
  - The Characteristics of ECEF
    - Originate at the center of the Earth
    - *xy*-plane : coincide with the Earth's equatorial plane
    - +*x*-axis : Point in the direction of 0° longitude
    - +*y*-axis : 90° E longitude
    - +*z*-axis : Normal to the equatorial plane in the direction of the geographical north pole
  - The satellite position & velocity vectors must be available in the ECEF for GPS navigation problem
  - In the case of GPS positioning, Cartesian coordinates (*X*,*Y*,*Z*) of the user's receiver are computed

WGS84 System

World Geodetic System (WGS84)

- Standard physical model of the Earth for GPS
  - The Characteristics of WGS84
    - Originate at the center of the Earth
    - a : 6378.137 km = Mean equatorial radius
    - b : 6,356.7523142 km
    - e : Eccentricity of Earth Ellipsoid = 0.0818
    - c : speed of light = 299,792.458 km/s
    - f : flattening = 1 - b/a
    - e' : second eccentricity = eb/a = 0.0820944379496

WGS84 System

Geodetic Coordinates System

- ECEF coordinate with the reference ellipsoid (for example WGS84) called Geodetic coordinate
  - So called Geographic coordinate system
- Geodetic longitude (λ)
  - The angle between the user and the x-axis measured in the xy-plane
- Geodetic latitude (ϕ)
  - The angle between the ellipsoid normal vector & projection of it into the equatorial plane
- Geodetic height(h)
  - *Relative to the WGS84 ellipsoid not to the geoid*
  - *Minimum distance between the user and the reference ellipsoid(i.e. ellipsoid normal)*

GPS Height

Height

- Geodetic (Ellipsoidal) Height; h

: The height above the ellipsoid. Ellipsoidal height is geometric, not a physical parameter and is what is given by the GPS technique.

- Orthometric Height; H

: The height above MSL. Orthometric height is a physical parameter and is what is given by most conventional surveying techniques. It is the level surface that a body of water will conform to. In this section (H) is obtained using the GPS observed ellipsoidal height (h) and correcting it with the Geoid/Ellipsoid separation (N) and the geoid model. For all pillar type HPN this value can be compared with the leveled height.

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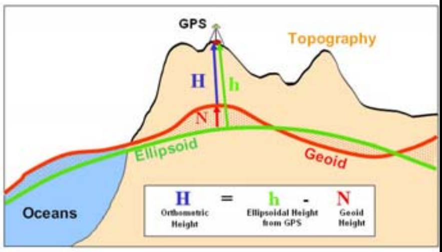
GPS Height

Height

- Geoid ellipsoidal separation (N):

: Is the distance between the ellipsoid and geoid at a specific point and is also known as the Geoid Undulation. The separation added to the orthometric (sea level) height (H), results in the ellipsoid height (h). The following formulae is of particular importance with the use of GPS.

$$h = H + N$$



where

h = is the ellipsoidal height
(height usually obtained with GPS)
H = is the orthometric height (sea-level)
N = is the geoid ellipsoidal separation

GPS Height

Height

GPS-H:

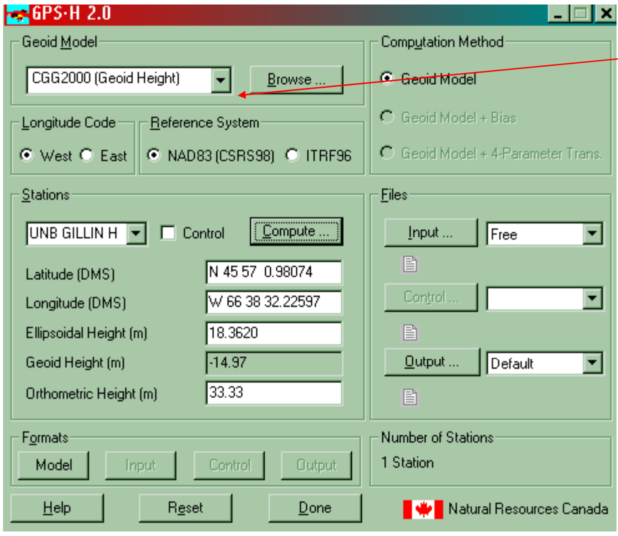
· GPS Height Transformation Packages.

· http://www.geod.nrcan.gc.ca/tools-outils/gpsh_e.php

· Online or Offline programs are provided. Offline program, called “gpsh-e.zip” released on Nov. 2001, is Win16 environment. Please check your computer to install it.

GPS Height

Height



Geoid Model:

CGG2000 – Canadian Gravimetric Geoid model 2000 is a scientific model of the geoid for North America from gravity data up to 2000.

GPS Height

Height

The Geoid model contributes to the vertical component of the reference system so that ellipsoidal GPS heights can be converted to orthometric elevations for practical uses.

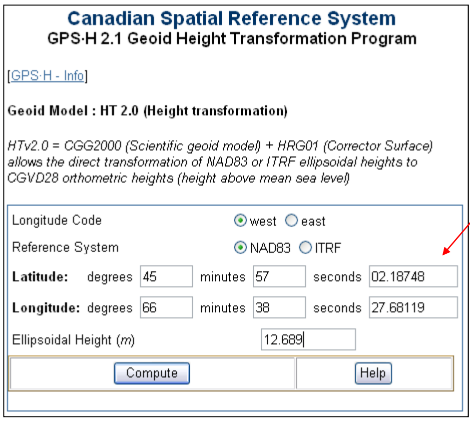
The real challenge lies in knowing the relationship between the ellipsoid and the geoid. Once we determine the difference between these two surfaces, called the "geoid-ellipsoid separation" or "geoidal height", at a given point, we can then apply the geoidal height to our GPS height measurement to get the mean sea level elevation. (from NRCan website)

GPS Height

Height

Online Service (from NRCan website)

http://www.geod.nrcan.gc.ca/apps/gpsh/gpsh_e.php



Please input coordinates manually