Applied Terrestrial Laser Scanner in active volcano crater: correction to velocity and geometry

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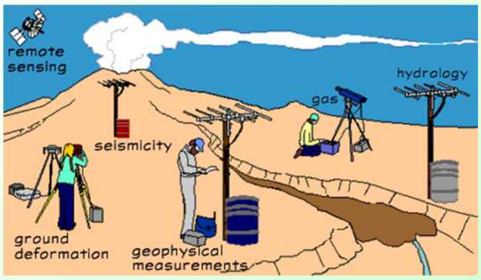
Volcano Monitoring Methods



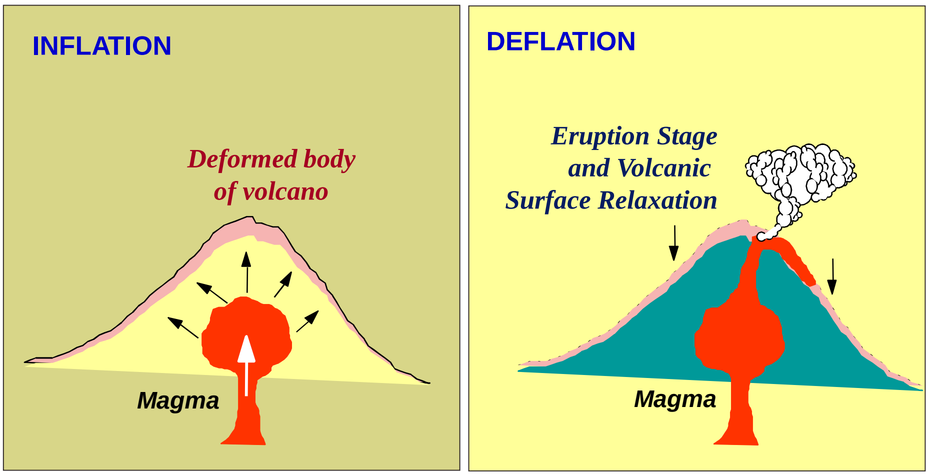
http://volcanoes.usgs.gov/

- Visual
- Seismic
- Deformation
- Chemical
- Thermal
- Microgravity
- Geomagnetic
- Remote Sensing

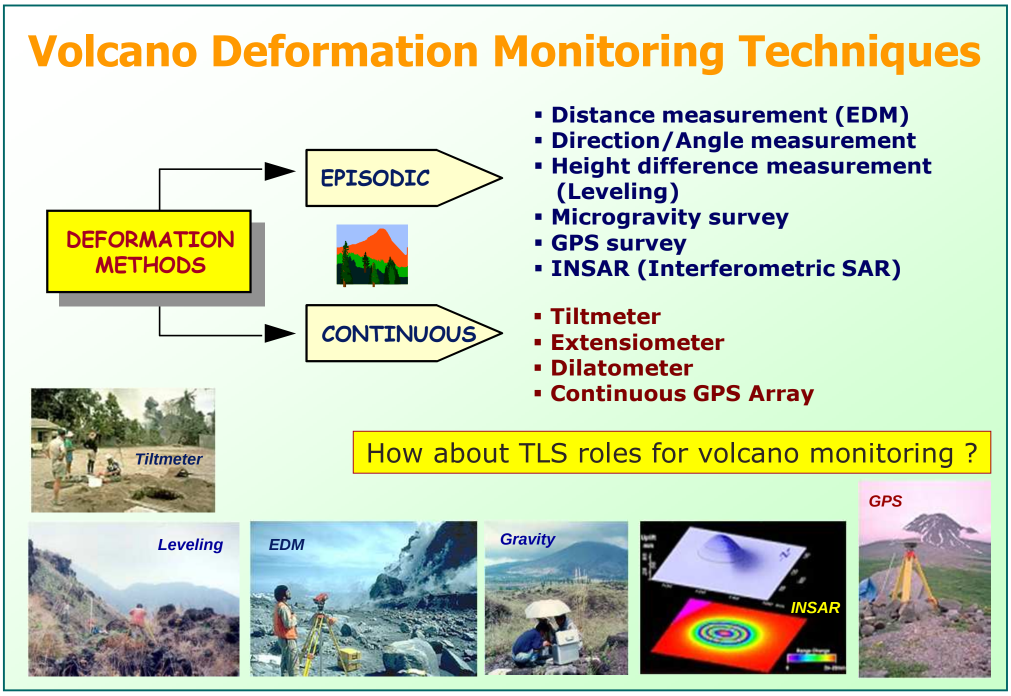
- ***Episodic***
- ***Continuous***

Hasanuddin Z. Abidin, 2005

Volcano Deformation



Hasanuddin Z. Abidin, 2001



TLS Roles for Volcano Monitoring

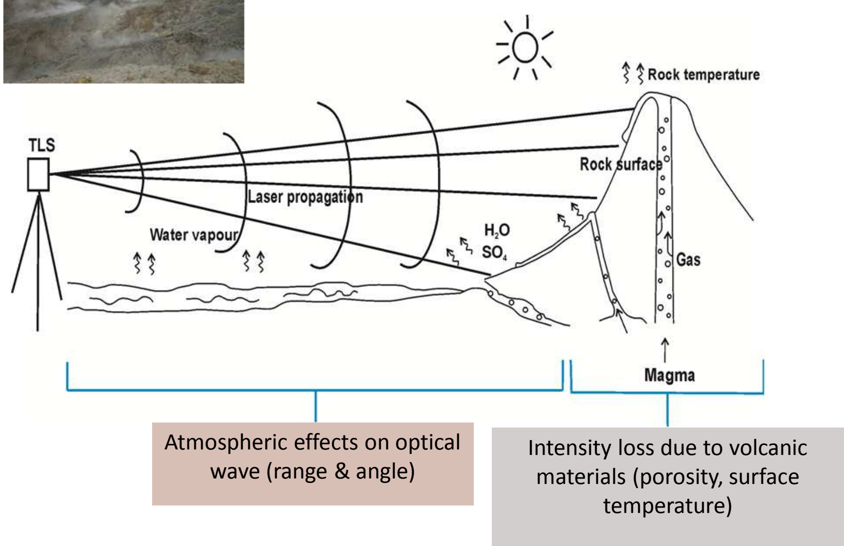
- 3D topographic mapping
- 3D geomorphological mapping
- Deformation monitoring

of volcanic areas of interests (e.g. craters, domes, cracking flank etc.)

Environmental Errors in TLS Measurement

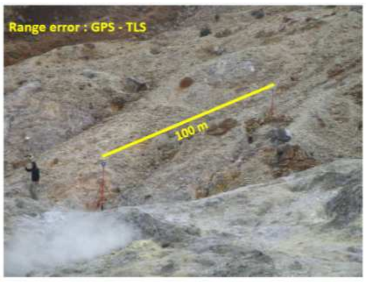
PARAMETER	EFFECT
(1) Internal /equipment temperature	Data distortion.
(2) Temperatute of scanned objects	Background radiation, degraded SNR, low precision.
(3) Atmospheric variation (air temperature, humidity, pressure)	Refraction index, disturbing of EM propagation, pixel dropout.
(4) Dust or vapors/gases	Edge effects, false return/multiple return pulse.

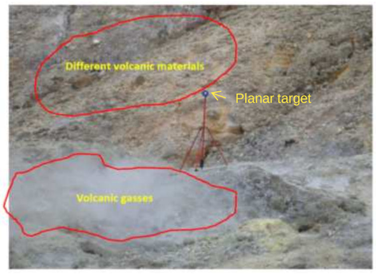
ILLUSTRATION OF VOLCANO'S ENVIRONMENTAL EFFECTS INTO TLS ENVIRONMENT

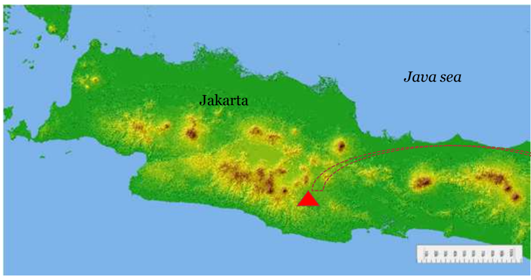


EXPERIMENT DESIGN

- Three targets were placed at distances of 50, 100 and 150 m.
- Type of TLS used is Leica ScanStation C10 which has maximum scope of 300 m.
- 50 times pick point for each target.
- Location of three targets then substituted by GPS geodetic measurement to get data comparison.
- TNDD TR-73U was use to record temperature, humidity and air pressure. One unit of TNDD was placed each at target and TLS stand station.







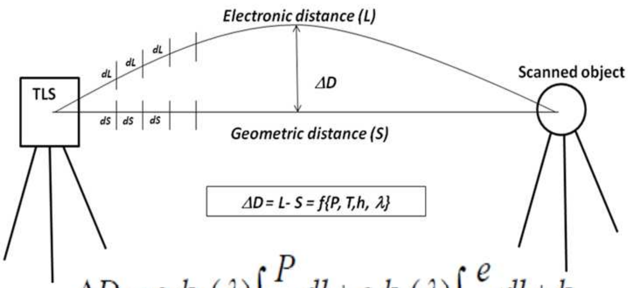
LOCATION

Active crater of Papandayan Volcano – West Java

Description

Last eruption in 2002. Recent activity is dominant of suphuric gases (SO_2) emission, temperature of gas holes 106-220°C, no vegetation covering, loose volcanic rocks, white-grey-green color of altered volcanic rocks. Rocks temperature near gas holes is ~70°C.

CORRECTION METHOD



$$\Delta D = c_d k_d(\lambda)\int \frac{P}{T} dl + c_v k_v(\lambda)\int \frac{e}{T} dl + k$$

Where:
ΔD : corrected distance
$k_d(\lambda)$, $k_v(\lambda)$: dry/water vapor dispersion constans for the phase optical refractivity.
c_d, c_v : velocity of light in dry/water vapor.
dl : measurement distance by TLS (m)
P : atmospheric pressure (mb)
T : temperature of air (°C)
e : partial water vapor pressure (mb)
k : constant

PRELIMINARY RESULT AND DISCUSSION

GPS MEASUREMENT

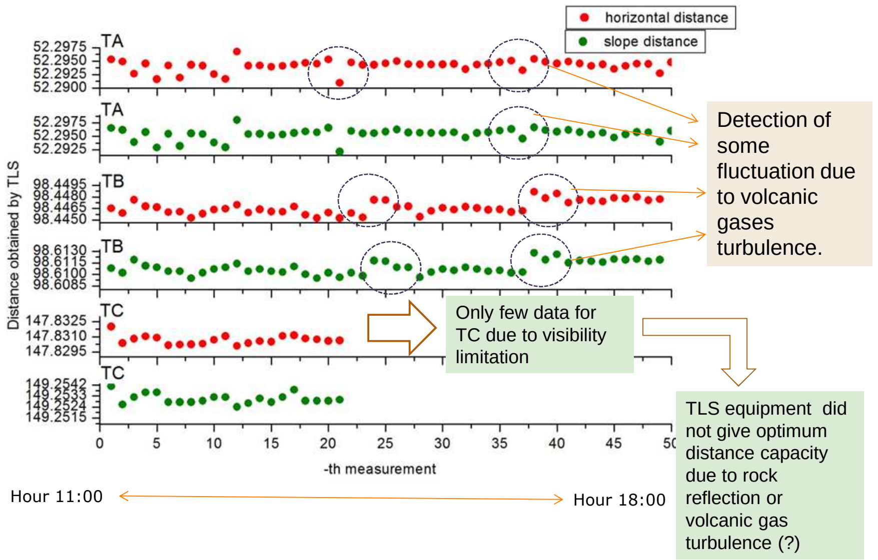
GPS data was obtained by Topcon GR3 (rover), Trimble 4000 SSI (reference), and processed using Leica GeoOffice v.8. Baseline calculation between TLS stand and each targets give results as seen in table below. TA,TB and TC refers to number of target. BASE is GPS reference point at Papandayan Volcano Observatory (~ 8 Km from the crater).

Baseline	Slope distance	Horizontal distance
BASE-TA	52.3006	52.3193
BASE-TB	98.6192	98.4931
BASE-TC	149.2783	147.9143

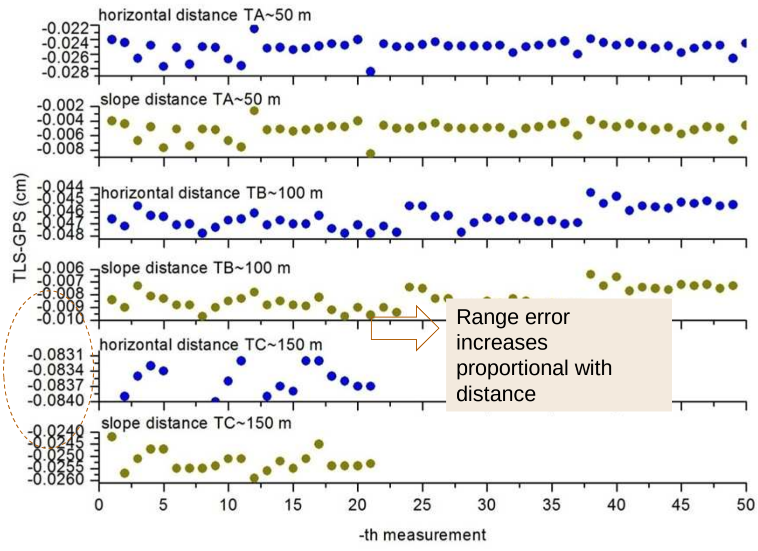
Range error = $GPS_{distance} - TLS_{distance}$

Use assumption no atmospheric effect due to short baseline

Results of TLS measurement (target pick point)

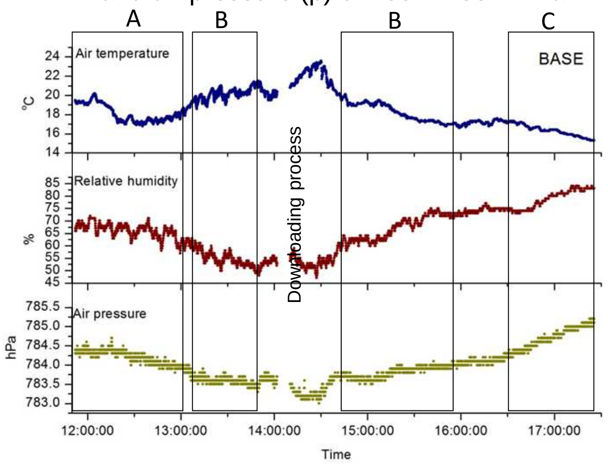


Range error (cm):



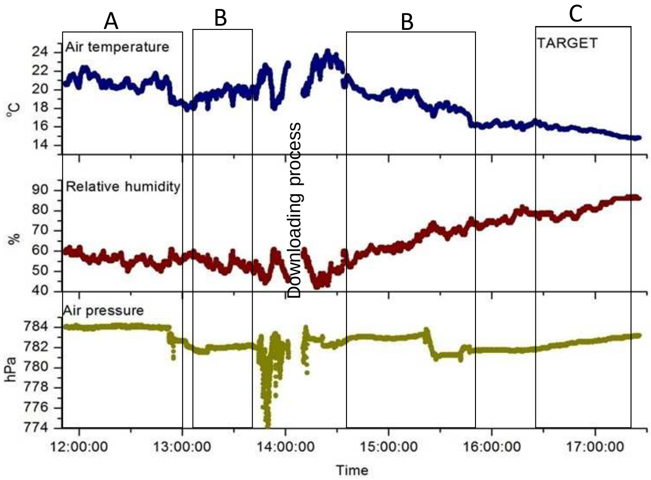
Local atmospheric data at TLS station

Air temperature (T) range of 15.3-23.6 ° C, 83-53% of relative humidity (h), and air pressure (p) of 785.1-783.2 hPa



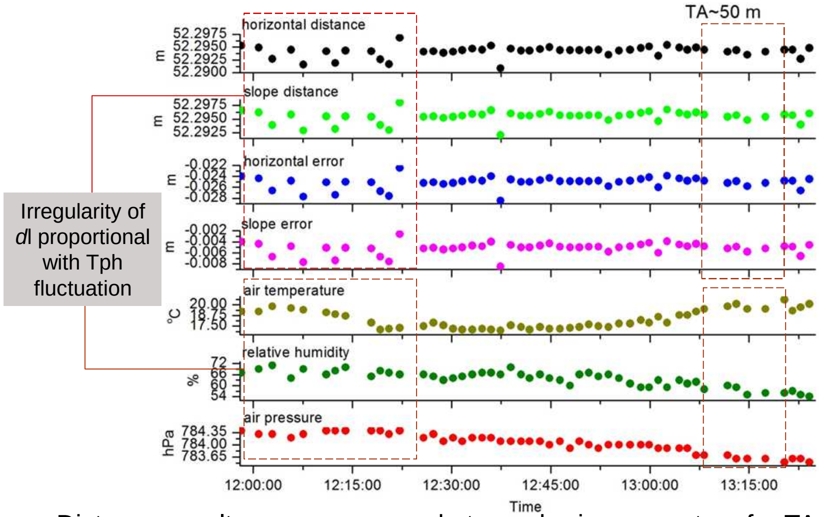
(T,h,p) at TLS stand during the measurements, data recorded every 5 second. Range of Thp values beetwen TLS and targets is not much different, and although its fluctuated during the measurement period but showed the same pattern.

Local atmospheric data at targets

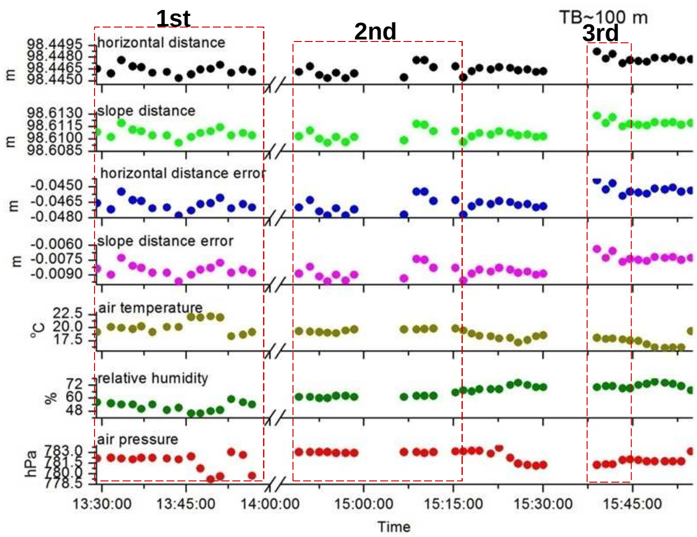


Temperatures at the targets has range 14.7-24.2 °C, 87-43% of relative humidity, and air pressure of 783.1-782.1 hPa. Data recorded every 5 second. Data during TB measurement was disturbed due to downloading process.

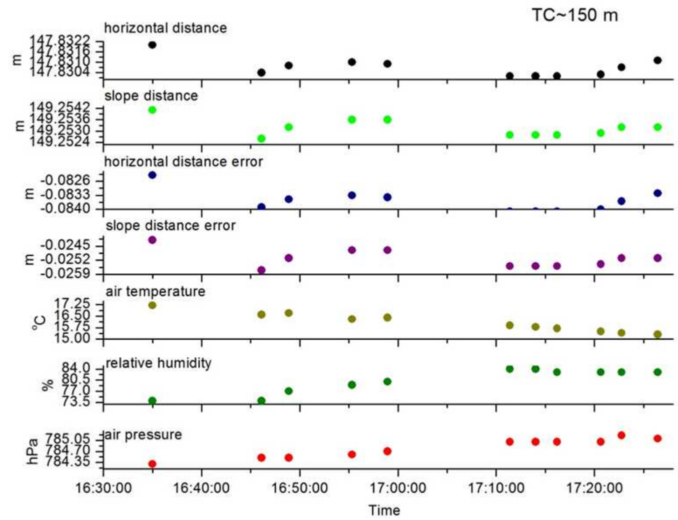
Corrrelation of distance measurement and atmospheric parameters (using Tph at the targets)



Distance results, range error and atmospheric parameters for TA ~ 50 m. TA is the closest target to gas emission source, experienced more turbulence at the beginning of measurement.



Pick target results, range, error and atmospheric parameters for TB ~ 100 m. Fluctuated if emitted gases passes in front of target. Correlation of *dl*, range error and Tph at 1st part, but no correlation at 2nd and 3rd part, possible due to reduce of gas concentration (?).



Pick target results, range, error and atmospheric parameters for TC ~ 150 m. Less fluctuated due to its distant area from volcanic gas source, but experienced limited visibility, possible related with volcanic gas obscured.

Application of correction model

Horizontal and slope distance from TLS corrected using first velocity correction (K1), second velocity correction (K2) and geometry correction (K3) as formulated by Rueger (1990).

Horizontal distance correction.

	A~50 m Average correction (m)	B~100 m Average correction (m)	C~150 m Average correction (m)
K1	$-1.149x10^{-2}$	$6.846x10^{-3}$	$9.825x10^{-3}$
K2	$-4.479x10^{-11}$	$-1.714x10^{-10}$	$5.020x10^{-15}$
K3	$-1.092x10^{-7}$	$-6.678x10^{-10}$	$-5.867x10^{-13}$

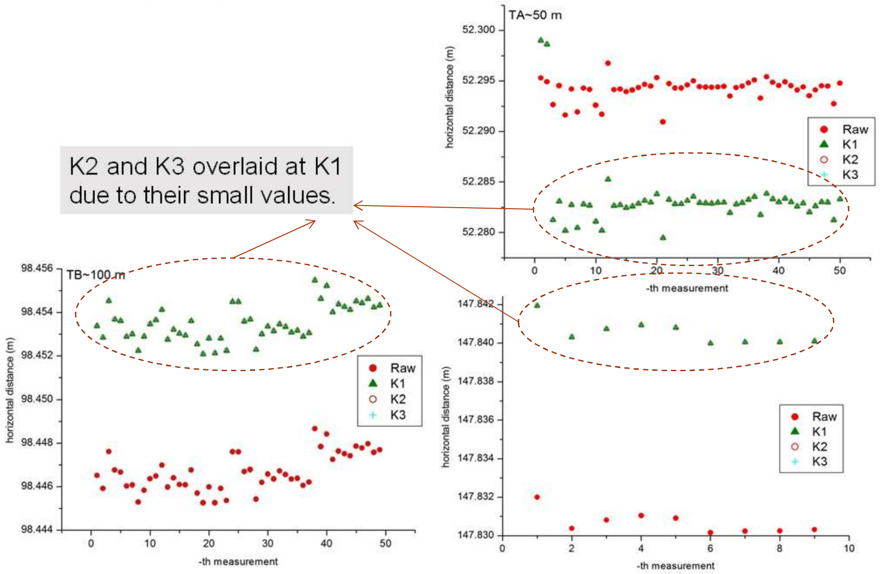
Slope distance correction.

	A~50 m Average correction (m)	B~100 m Average correction (m)	C~150 m Average correction (m)
K1	$-1.149x10^{-2}$	$6.857x10^{-3}$	$9.920x10^{-3}$
K2	$-4.480x10^{-11}$	$-1.722x10^{-10}$	$5.069x10^{-15}$
K3	$-1.092x10^{-7}$	$-6.711x10^{-10}$	$-6.038x10^{-13}$

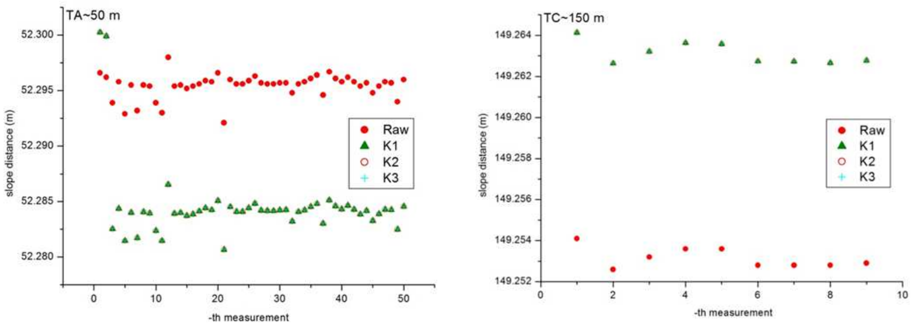
Summary of correction results

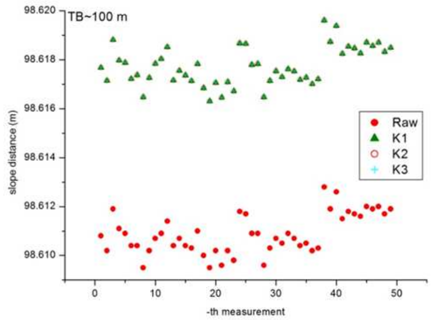
1. TA~50 m experienced shorter observed distance, while correction for TB~100 m and TC ~150 m show longer observed distances.
2. K1 correction shows significant value at each distance, even reaching a fraction of cm at TA~50 m.
3. K2 and K3 correction showed a very small value which is interpreted due to involvement of curvature spheroid variable (*R*, radius of the earth) in calculation, while the distance measured in this experiment is relatively short.

Plotting graph of initial measurement and correction



Horizontal distance correction for TA~50 m, TB~100 m, and TC~150 m.





Slope distance correction for TA~50 m, TB~100 m, and TC~150 m showed the same pattern with horizontal correction.

Preliminary Notes

Preliminary results of this research do not show the expected one, especially in correction results. K2 and K3 is not significant, possible due to some factors: short baseline, small elevation gradients, and insignificant Thp value between target and TLS stand.

Correction models of Rueger (1990) using Thp standard, and only involves CO_2 in the air. In this research, gas component is more varied (volcanic gases generally consist of a compound H_2O, N_2, CH_4, CO, CO_2, SO_2, H_2S, HCl, NH_3 and H_2O) that have different characteristics, so they have not been accommodated in this model.

CONCLUSION

From preliminary analysis we drawn some conclusions as follows:

1) Activity of volcanic gases and local atmospheric conditions of active volcano crater effect distance value obtained by TLS measurement, and has significant error value proportional with increasing of distance.

2) Correction of distance measurement only significant for first velocity correction, while second velocity correction and geometric correction is not significant.

FUTURE WORKS

1) Apply Zenith Hydrostatic Delay (Saastamoinen, 1972).
2) Compared and reviewed to determine the most suitable model. evaluate design of measurement
3) Deploy the same method at normal/non volcanic environment. Result from volcanic and normal environment will be compare to see some possible solutions.
4) Looking for another correction model also essential to get better result or if necessary create new correction formula.

- THANK YOU -