INTRODUCTION

Direct levelling is performed extensively in the CERN surveying processes for accelerator elements’ alignment and positioning. LGC software (Logiciel Général de Compensation) computes results and associated statistics for observations used by surveyors. Traditionally, direct levelling campaigns are computed separately from the planimetry, using simple differences of height -called in LGC *DVER observation- between two measured points. LGC provides another observation model, called *DLEV, using offsets to a horizontal plane at the position of the station. The level planimetric position must therefore be known or be computable by additional observations. This more rigorous model allows a better integration in 3D computation involving other instruments, such as laser trackers or total stations.

OBSERVATION MODELS

2 levelling observation models are available in LGC:

* DVER
  - Simple difference of height between 2 points
  - Used in the normal process

* DLEV
  - Offset with respect to a horizontal plane
  - Not used in the normal process

CURRENT PROCESS

Standard levelling campaign from points A to B:

Steps | Interface | Computation process
---|---|---
Field Observations | SMART / TSUNAMI | Observations registered
Storage in Survey Database | GeoGEO | Instrument Calibration
Least Square computation | LGC ++ | 1D computation

DRAWBACKS

Earth Curvature correction:
- Only applied if the distance station to grade rod is observed
- Mix of corrected and non-corrected observations in the adjustment

* DVER:
- Preferably used in a separate 1D computation
- No geoid model considerations

The current process is not suited for mixing direct levelling observations with other instruments (Laser Trackers,…) in 3D Computation.

* DLEV is more appropriate to take into consideration the geoid model, but the station position must be known or computable.

TEST CASE

Large Hadron Collider levelling campaign between ATLAS and LHCb:
- ~2.65 km of direct levelling
- Horizontal distance station to grade rod measured
  → Position of the levelling stations known within a precision (1σ) of 5 to 11 mm
- 1 point fixed as reference close to point 8 (LHCb)
- Fairly straight levelling path along the accelerator
- Neither biased nor gross errors in the data

The influence of the geoid model and the station precision is evaluated.

GEOID INFLUENCE

3 geoid models are used at CERN: SPHERE, CG1985 and CG2000

Figure 3: (a) Difference in height of geo-referenced SPHERE, CG1985 and CG2000
  - *DLEV computations to a reference *DVER computation
  - (b) Difference between CG2000 and CG1985 along the LHC Tunnel

SPHERE/CG1985:
- Simple geoid model → Earth curvature corrections are good enough
  → Negligible differences

CG2000:
- More complex and accurate geoid model → More vertical deviations
  → Non-negligible differences

STATION DETERMINATION KNOWLEDGE

Figure 4: (a) Standard deviations of the fiducials’ altitudes with gaussian errors introduced on the station positions (300 simulations)
  - (b) Average of the fiducials’ altitudes with systematic longitudinal variations on the station positions (300 simulations)

Figure 4a shows that the influence of the station position knowledge is not that critical. For this measurement configuration, the decrease in the altitude precision (1σ) is of about 0.04 mm after 2.65 km of direct levelling if the station is known within a standard deviation of 5 m.

But any systematism (Fig. 4b) should be avoided longitudinally to the accelerator/levelling path. It highly impacts the result.

CONCLUSION

Knowing the position of the levelling stations is crucial in 3D computing environment to take into account the geoid influence for long stretch of surveying operations.

The precision of the station is not that sensitive, knowing it within a couple of meters would be fine for the CERN surveying activities.

Easy, reliable and fast solutions should be found to register the levelling station positions on the field. Solutions can be on the software, hardware and/or process levels.