Swedish User Guidelines for Network RTK

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Background and objectives

Services based on permanent GNSS reference stations, e.g. SWEPOS™ in Sweden, have made it possible for basically anyone to use the technique. The need of user guidelines for this technique is essential (Norin et al. 2006)

Errors can be introduced into the positioning if the users have no knowledge, or information, about the factors affecting the observations e.g.:

1. the satellite constellation
2. settings in the receiver
3. multipath errors
4. ionospheric and tropospheric errors
5. temporal correlations, etc…

Swedish User Guidelines

Settings and quality indicators in the GNSS receiver:

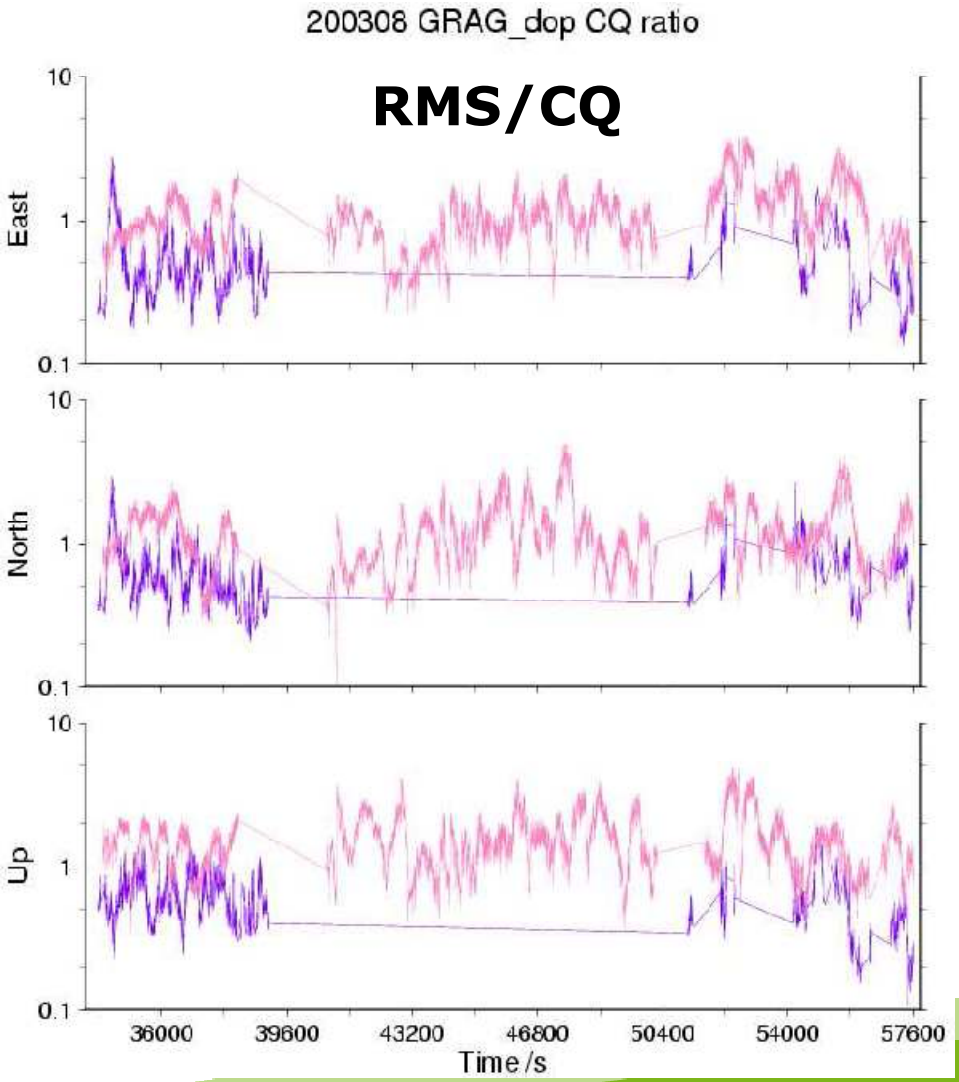
1. The elevation cut off angle is recommended to 13-15 degrees for today's satellite constellation

2. PDOP recommendations are set to maximum 2-4 depending on the uncertainty requirements

3. The instrument-reported coordinate quality measures should (most manufacturers) be multiplied by 2 for at least 95% confidence level (2σ). Additionally, the user should be aware of that these uncertainties might be well-underestimated

4. E.g. multipath effects for a short period of time (seconds to minutes) are not included and modeled into these instrument-reported values

Example of an uncertainty and PDOP filter (Edwards et al. 2008)



Filter:

- Horizontal CQ < 50 mm
- Vertical CQ < 100 mm
- PDOP < 3

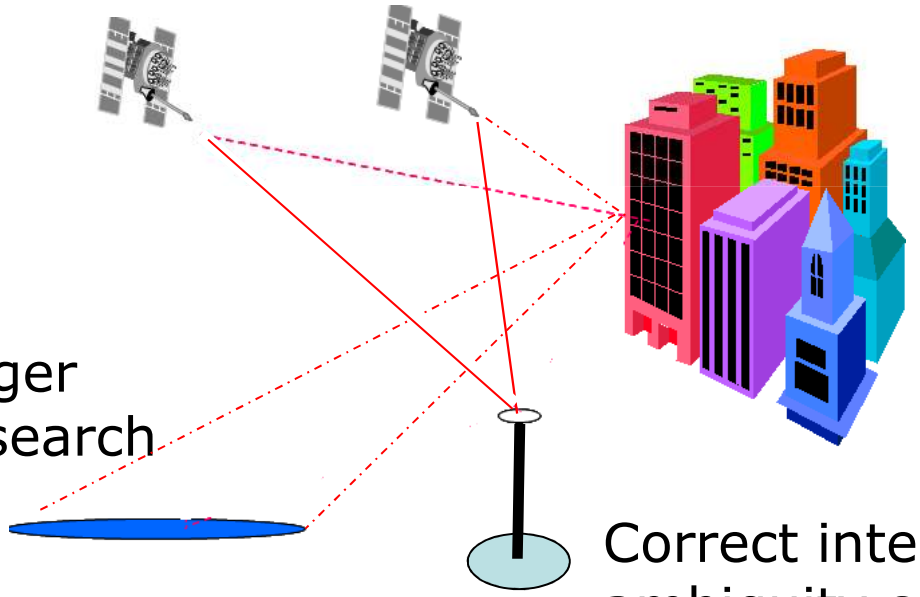
Multipath affected area: the pink network RTK equipment gave over-optimistic CQ values

Environments with multipath, large distances or height differences to reference stations might give CQ values that are over-optimistic by a factor 3-5

Integer ambiguity failure, or falsely estimated integer ambiguities

These failures might occur due to:

1. Multipath errors
2. Troposphere and ionosphere
3. Other errors



Wrong integer ambiguity search space

Correct integer ambiguity search space

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Surveying and control procedures:

- Control by **revisits** or **"known" points** during field work can be used to check all points measured with a certain fixed solution, or to check the previously obtained fixed solution (especially important for multipath affected areas)

- An accepted deviation for a **revisit** might be up to ± 60 mm horizontally and ± 80 mm vertically (at least 95 % confidence level and no tripod used)[1]

1 Law of error propagation:

$\sigma_{horizontal}$ = 15 mm

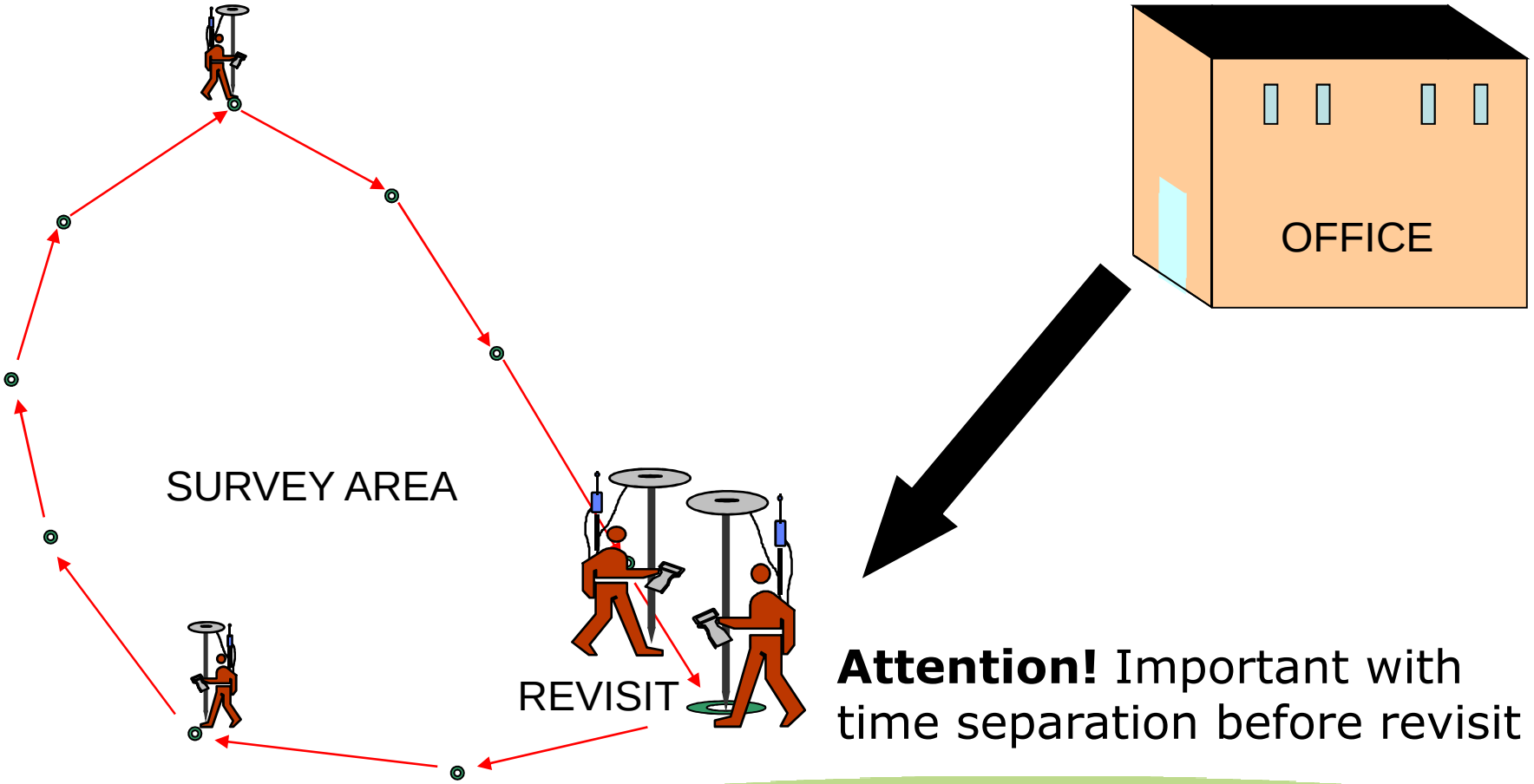
σ_{height} (ellipsoid) = 27 mm

$\sigma_{centering}$ = 14 mm

$$\Delta^{revisit}_{horizontal} = 2\sqrt{2\sigma_{horiz.}^{\,2} + 2\sigma_{cent.}^{\,2}} \approx 60\ mm$$

$$\Delta^{revisit}_{vertical} = 2\sqrt{2\sigma_{height}^{\,2}} \approx 80\ mm$$

Revisit



Attention! Important with time separation before revisit

Swedish User Guidelines cont.

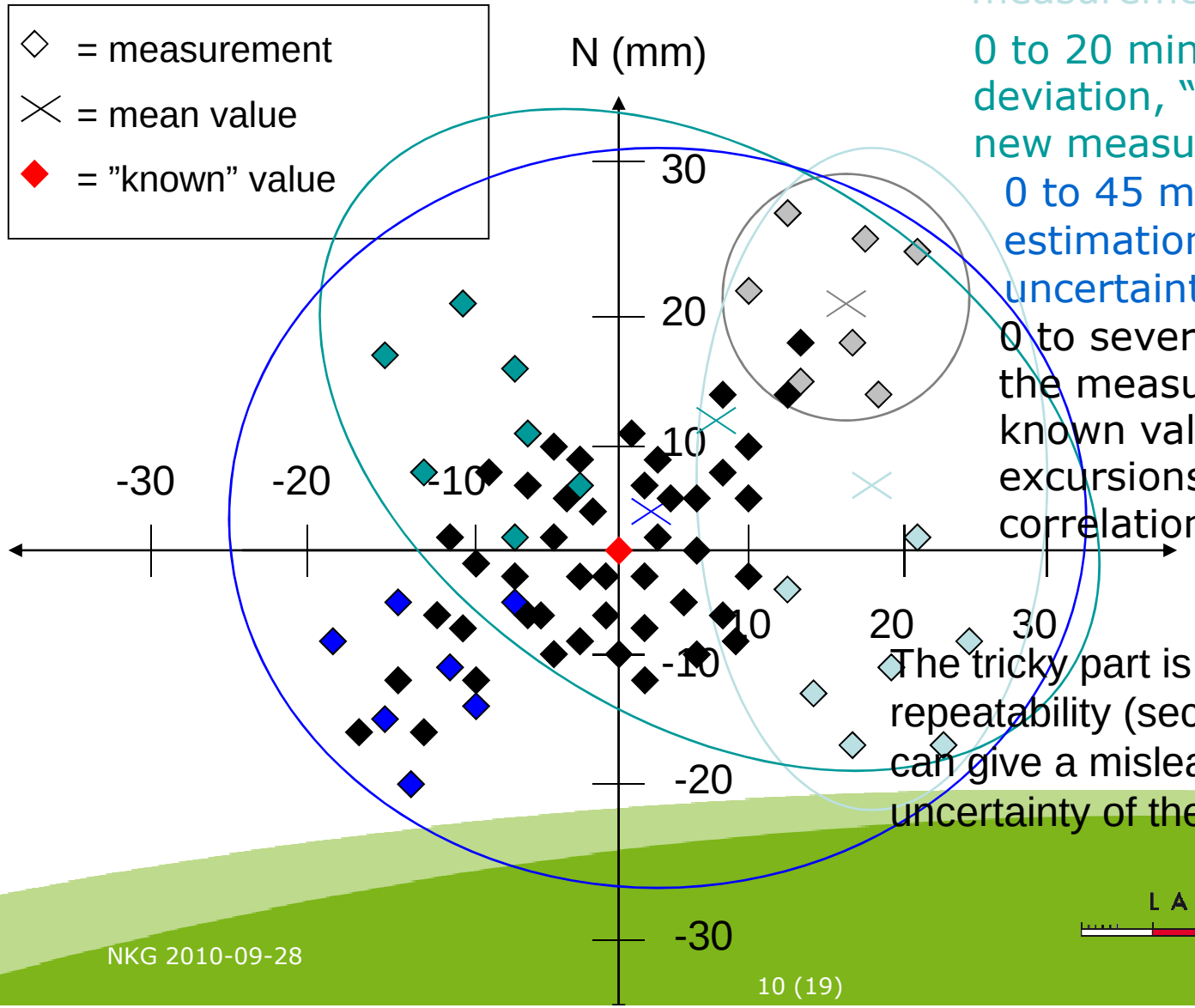
Revisit cont.:

1. Use a time separation of at least 5-10 minutes, even though **20-45 minutes** are preferred, to reduce temporal correlation effects and to assure a more confident estimation of the obtainable uncertainty

2. 20 minutes for the horizontal component and 45 minutes for the vertical component, based on ~70km between the reference stations (Odolinski 2010a)

3. Additionally it should be noted that revisits can be used to improve the uncertainty of the measured points by averaging (with a sufficient time separation)

Revisit of a point- the problem with temporal correlations



0 to 5 min: in reality a large deviation, “low uncertainty”

0 to 10 min: large deviation, “low uncertainty” for new measurements (5-10 min)

0 to 20 min: slightly smaller deviation, “low uncertainty” for new measurements(10-20 min)

0 to 45 min: a “true” estimation of the obtained uncertainty

0 to several hours: most of the measurements close to the known value with some excursions due to temporal correlations

The tricky part is that short term repeatability (seconds to minutes) can give a misleading impression of uncertainty of the measurements!

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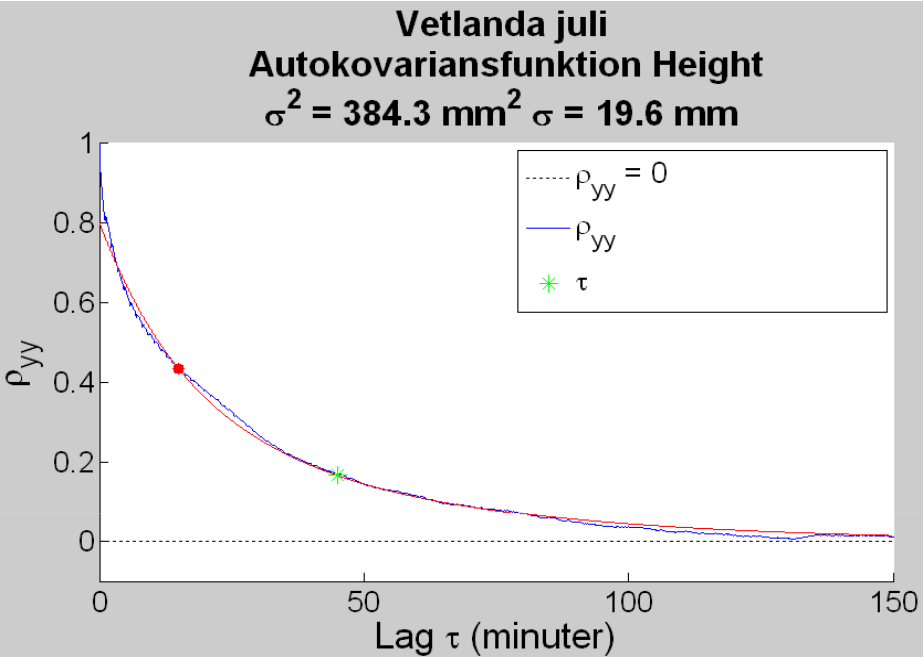
Correlation length estimates:



Modelled as a composite first-order Gauss Markov process

Time separation (minutes)	PRTK τ	PRTK Ω	NRTK τ	NRTK Ω
Horizontal	16.7	23.9	17.4	23,1
height	15.8	24,2	35.5	39,4

Odolinski 2010a: Study of accuracy and temporal correlations for Network RTK. Rapportserie: Geodesi och Geografiska informationssystem, 2010:2, Lantmäteriet, Gävle. (In Swedish). In print for an article in English

Swedish User Guidelines cont.

Control procedures cont.:

- An accepted deviation for a control of a **known point** might be ± 40 mm in the horizontal and ± 60 mm in the vertical component (at least 95 % confidence level and no error in the known point)[2]

2 Law of error propagation:

$\sigma_{horizontal}$ = 15 mm

σ_{geoid} = 15 mm

σ_{height} (ellipsoid) = 27 mm

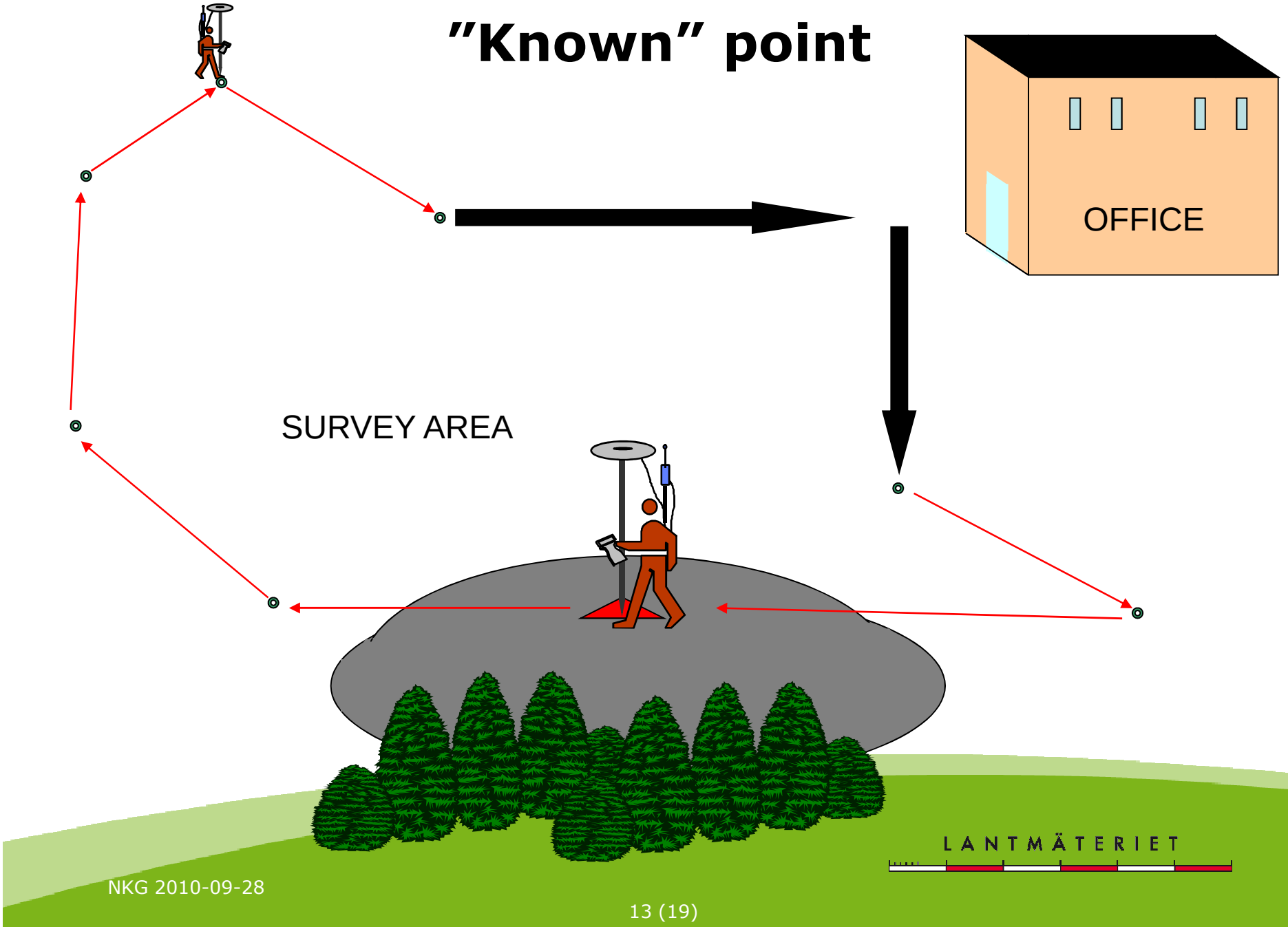
$\sigma_{centering}$ = 14 mm

$$\sigma_{(height+geoid)} = \sqrt{\sigma_{height}^{2} + \sigma_{geoid}^{2}}$$

$$\Delta_{horizontal}^{known\ point} = 2\sqrt{\sigma_{horiz.}^{2} + \sigma_{cent.}^{2}} \approx 40\ mm$$

$$\Delta_{vertical}^{known\ point} = 2\sqrt{\sigma_{(height+geoid)}^{2}} \approx 60\ mm$$

”Known” point



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Swedish User Guidelines cont.

Control procedures cont.:

- Use a **check point** close to the office on a regular basis (before and after surveying) to control the settings in the receiver, to investigate if atmospheric disturbances have affected the network RTK measurements, etc.

- An accepted deviation from a **check point** might be ± 30 mm horizontally and ± 50 mm vertically (at least 95 % confidence level, tripod used and no error assumed in the check point)[3]

3 Law of error propagation:

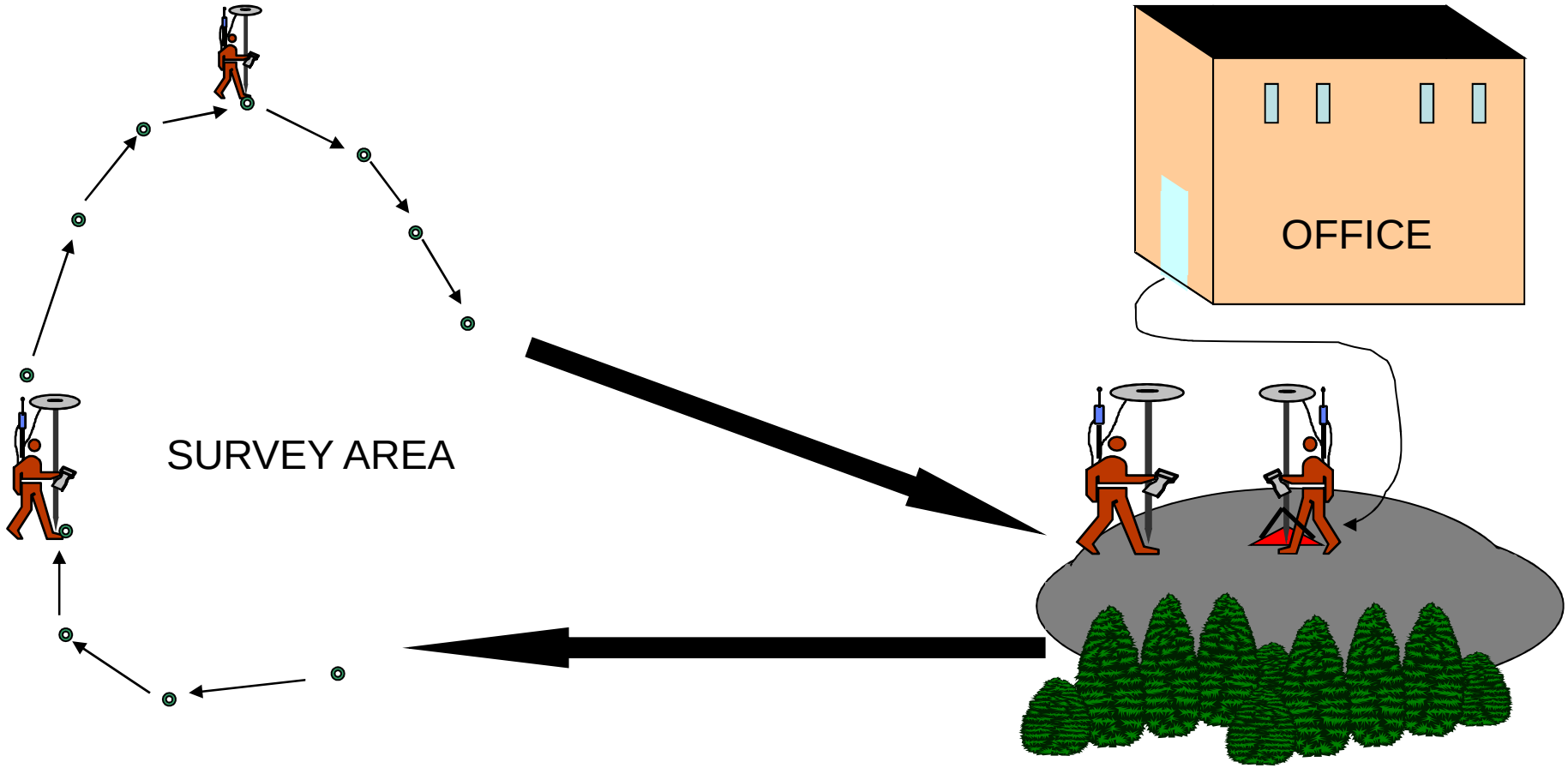
$\sigma_{horizontal}$ = 15 mm

σ_{height} (ellipsoid) = 27 mm

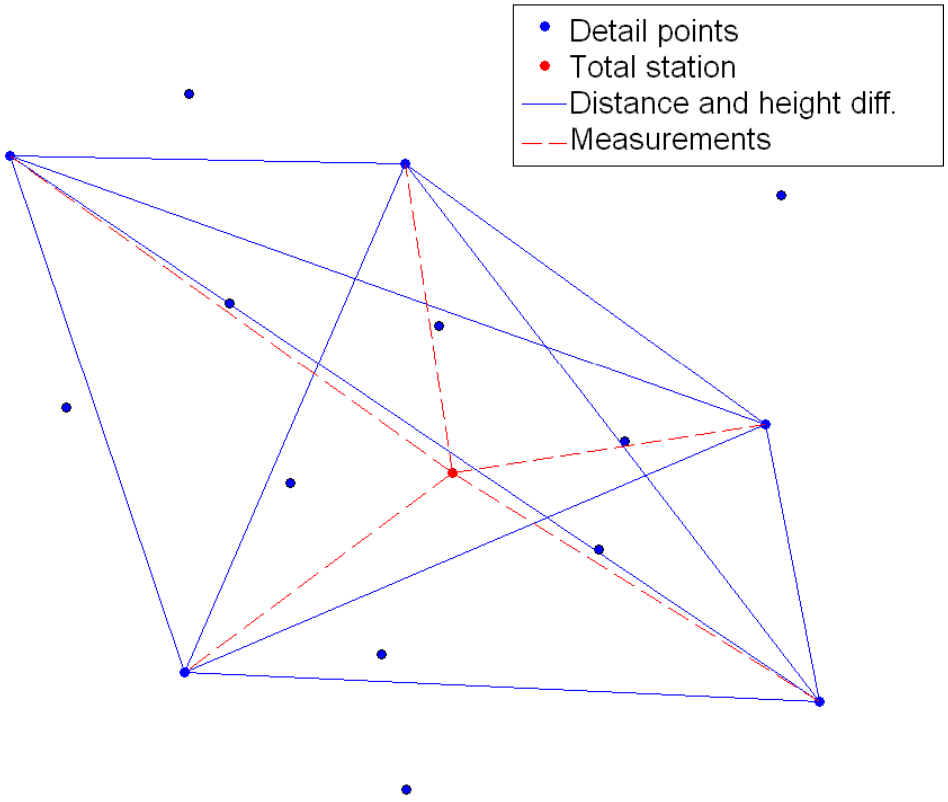
$$\Delta_{horizontal}^{check\ point} = 2\sqrt{\sigma_{horiz.}^{2}} \approx 30\ mm$$

$$\Delta_{vertical}^{check\ point} = 2\sqrt{\sigma_{height}^{2}} \approx 50\ mm$$

Check point close to office



Control method: ”Control with total station”



- The detail points are measured with a total station (free stationing) in a local system
- The measured detail points are then compared to the network RTK points (relative control)
- Integration of GNSS and total station is already upon us

Sun spot maximum

- Sun spot maximum in year 2013, will probably mostly affect the vertical component
- Indications: 85% of the time a correct integer ambiguity resolution is obtainable with present receivers, mean time to fix 55 seconds (based on ~70 km between reference stations) (Emardson et al. 2010, soon published)
- Outcome: SWEPOS will present a real time solar activity monitor available at http://www.swepos.com
- Daily space predicitions[4]
- The alternative is to control a **check point** close to the office which might give an indication of possible problems

4 http://www.swpc.noaa.gov/NOAAscales/index.html

Discussion

- The recommendations will probably improve over the years, and it is of great importance to keep the guidelines updated
- The expanded uncertainty levels will most likely improve with additional satellite constellations, e.g. Galileo
- Possible with a Nordic cooperation for User Guidelines for network RTK?
- In the future guidelines for GNSS integrated with a total station (e.g. Leica Smartstation or Trimble IS Rover), or possible integrated with INS (Inertial Navigation Systems), will be an important issue to consider

References

Edwards S, Clarke P, Goebell S, Penna N, 2008: An examination of commercial network RTK GPS services in Great Britain. School of Engineering and Geosciences, Newcastle University, Newcastle.

Henning W, 2008: National Geodetic Survey user guidelines for classical real time GNSS positioning. National Geodetic Survey, april 2008.

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Odolinski R, 2010b: Checklista för nätverks-RTK. Rapportserie: Geodesi och Geografiska informationssystem, 2010:3, Lantmäteriet, Gävle. (In Swedish)

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Questions?

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