Close-RTK:
An investigation of network RTK performance

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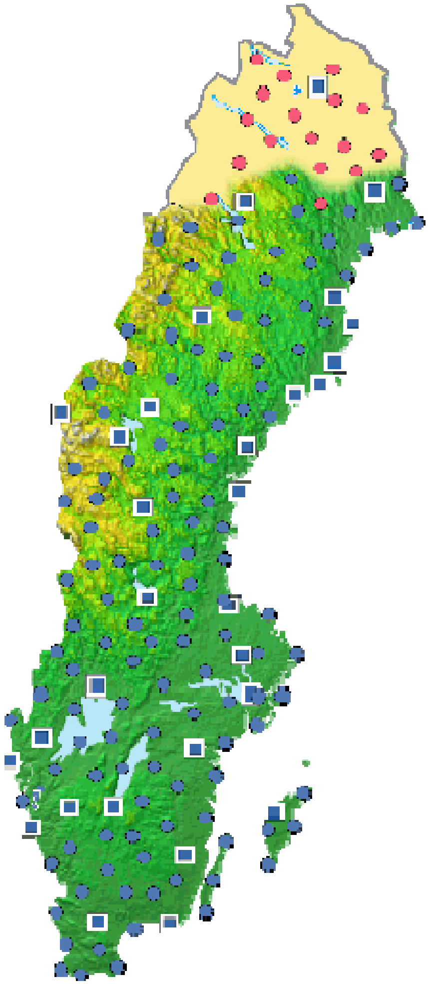
Background



- SWEPOS network-RTK service,
  - based on the VRS-concept,
  - ~70 km station distance
  - ~170 stations
  - ~1200 users
- Approximate accuracy (1σ)
  - vertical: ~25-30 mm
  - horizontal: ~10-15 mm
- Users always want better, faster, more accurate etc, but:
  - In general happy with the horizontal
  - Asks for improvements in the vertical

Main questions

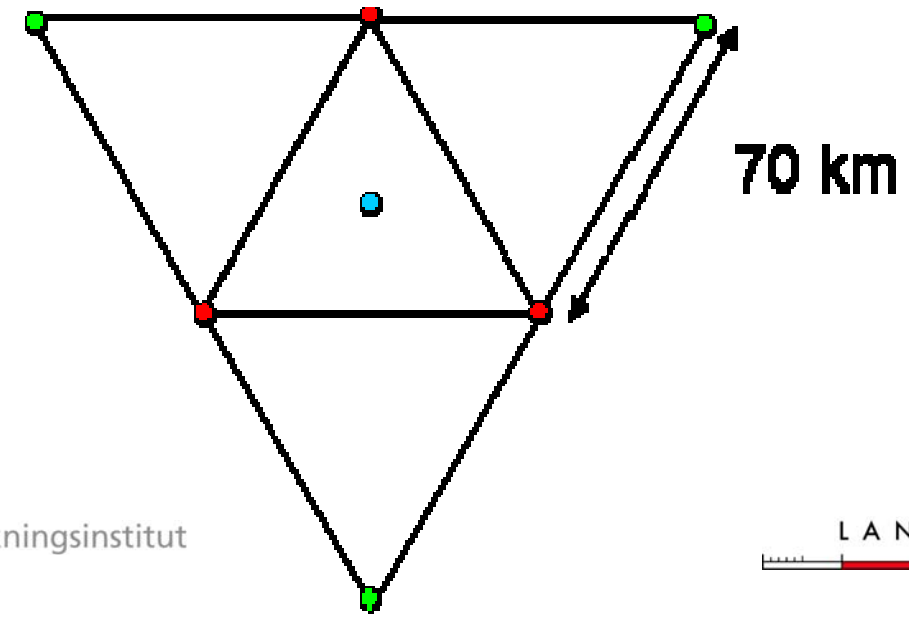
- What is the quality of real-time measurements with GNSS **based on a detailed studies of the contributing error sources**?

- What measures are needed in order to improve the accuracy?

Terminology

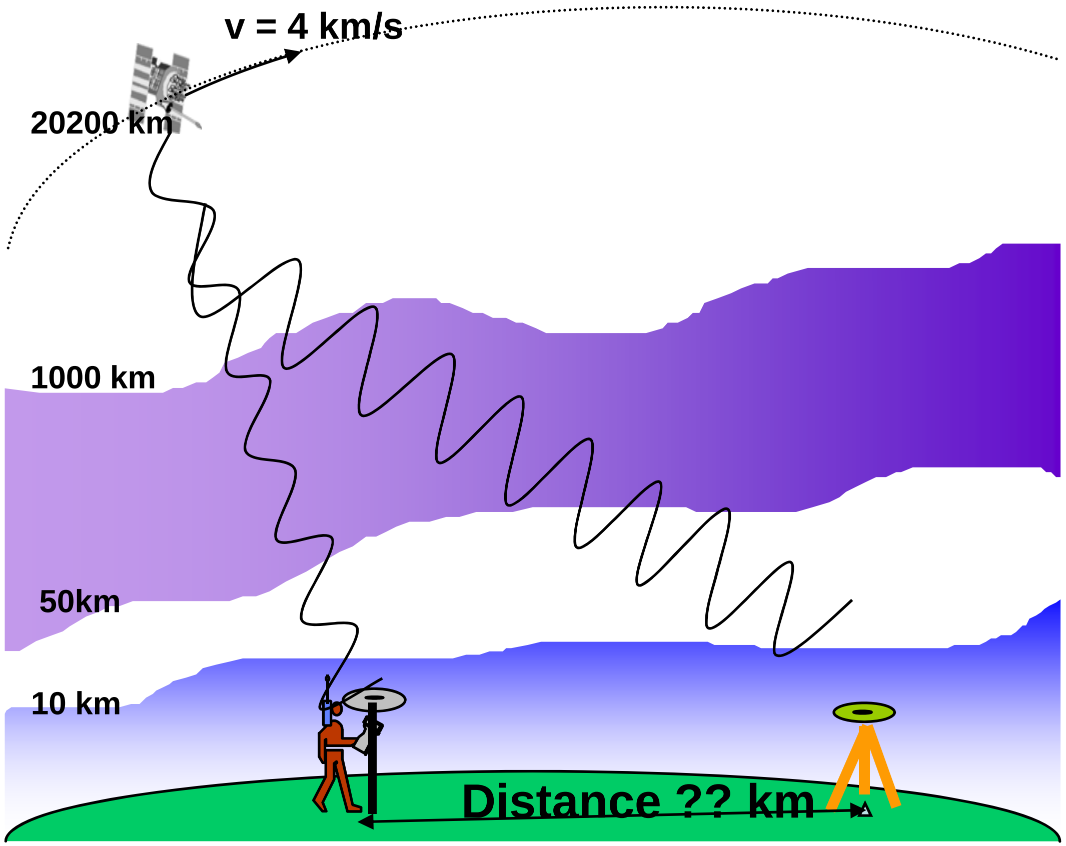
- All listed errors in this presentation corresponds to the square root of the variance of the difference between the measured and the true value. (1σ values)

- This means that the reported errors can be used to estimate the measurement uncertainty of the corresponding measurements.

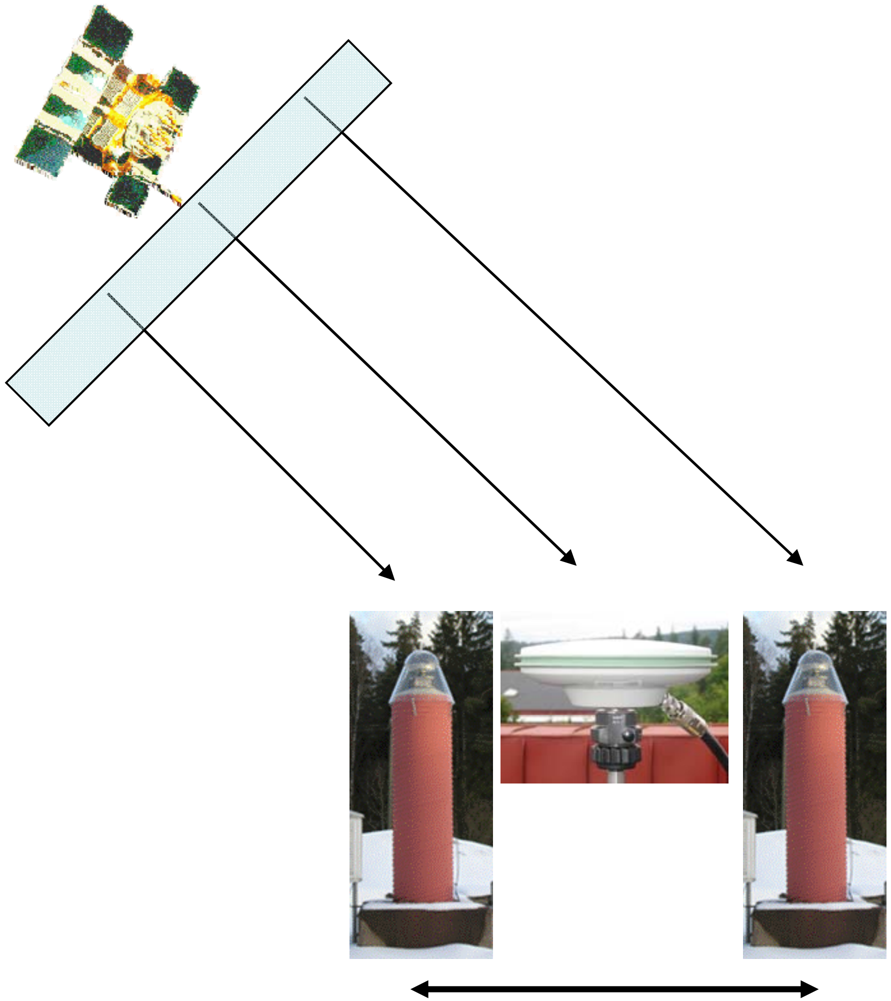


Error Sources

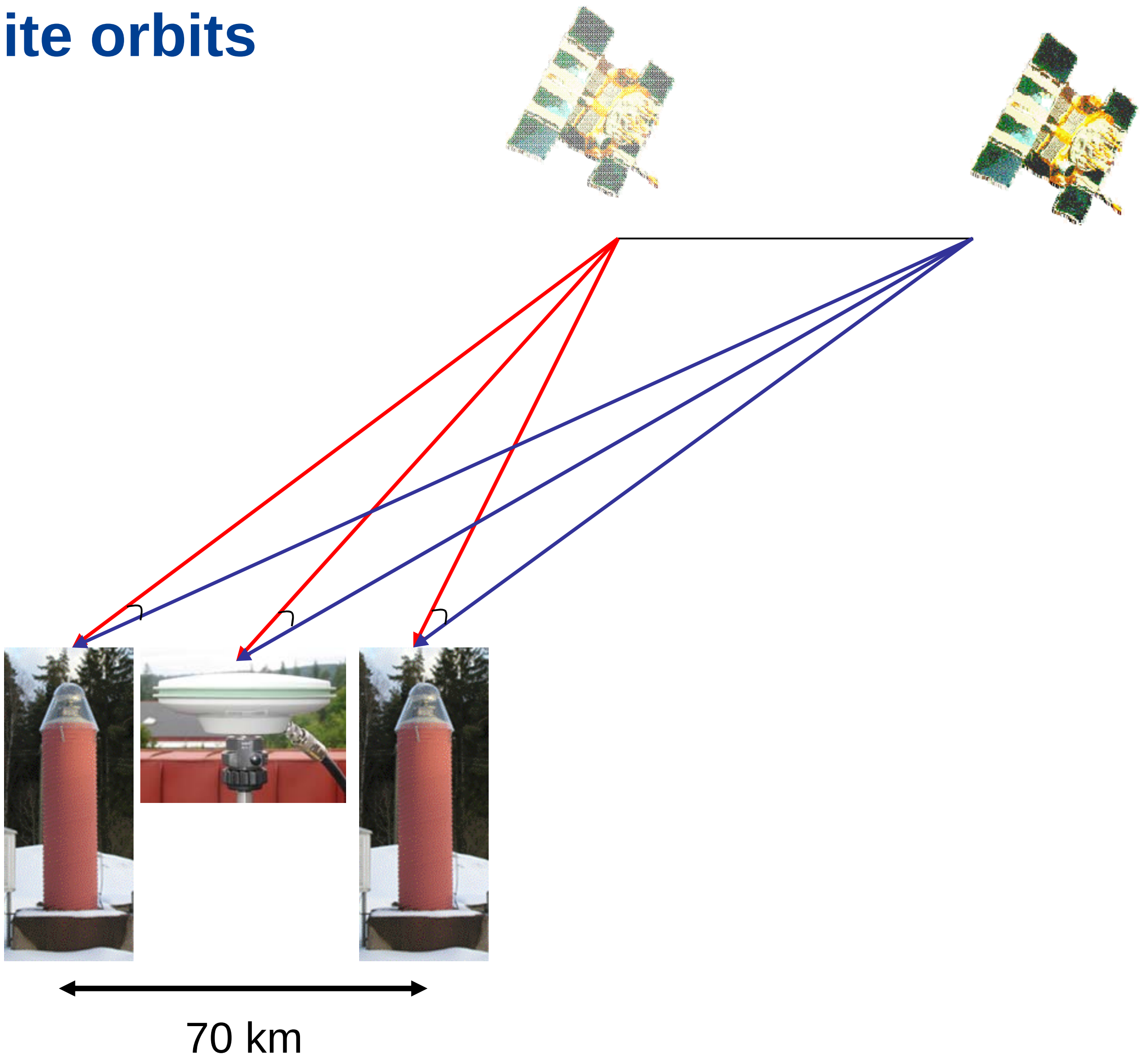
- Satellite clocks
- Satellite orbits
- Ionosphere
- Troposphere
- Local effects



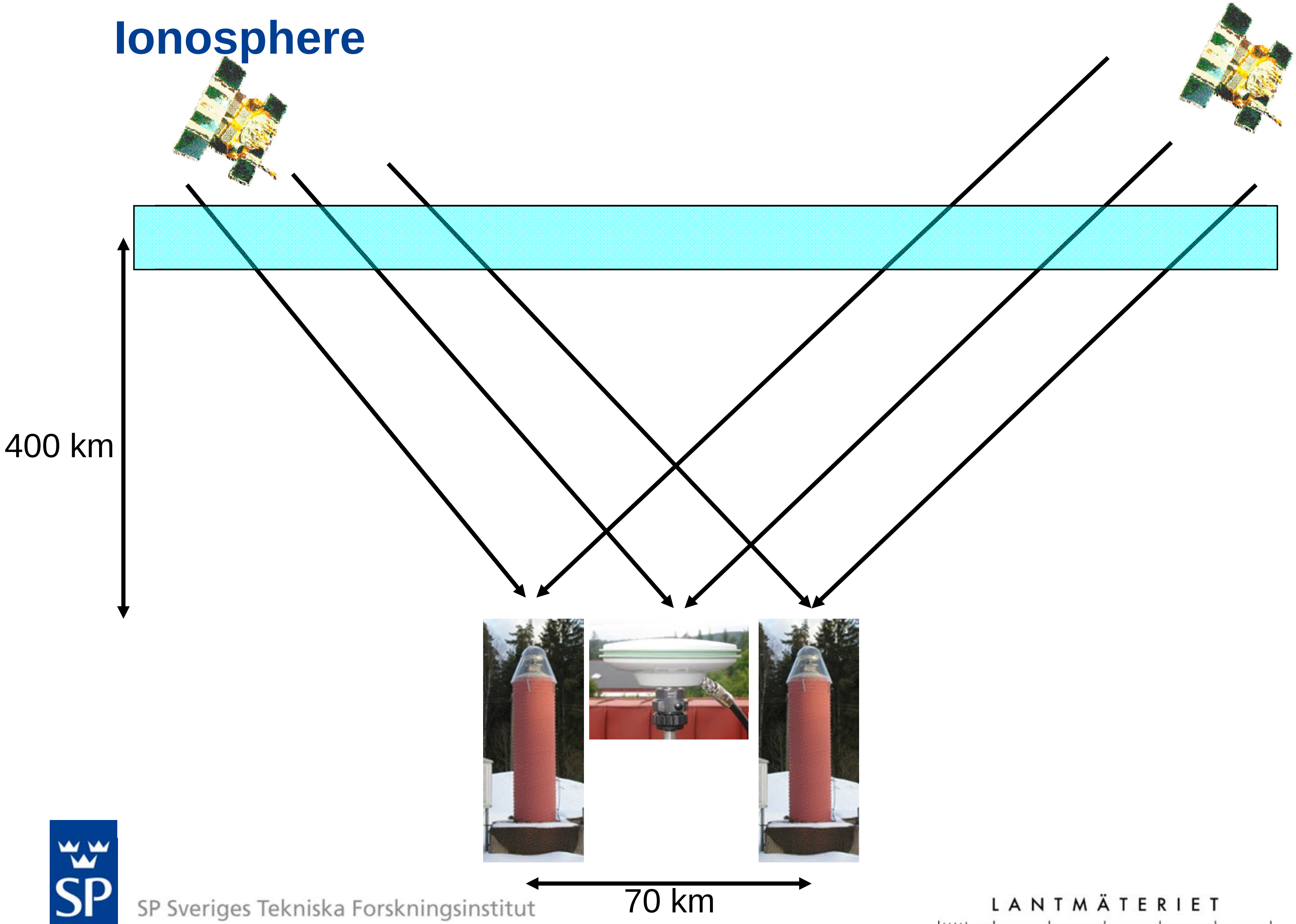
Satellite clocks



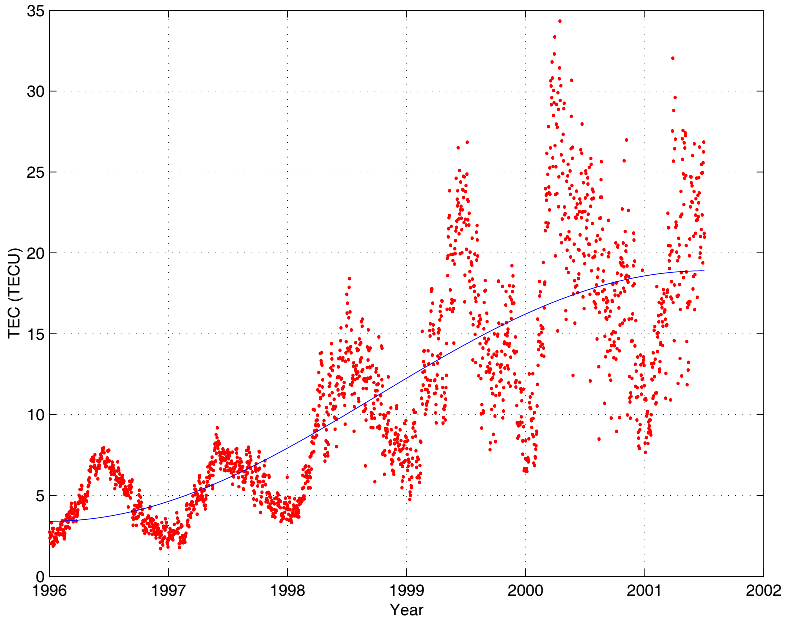
Satellite orbits



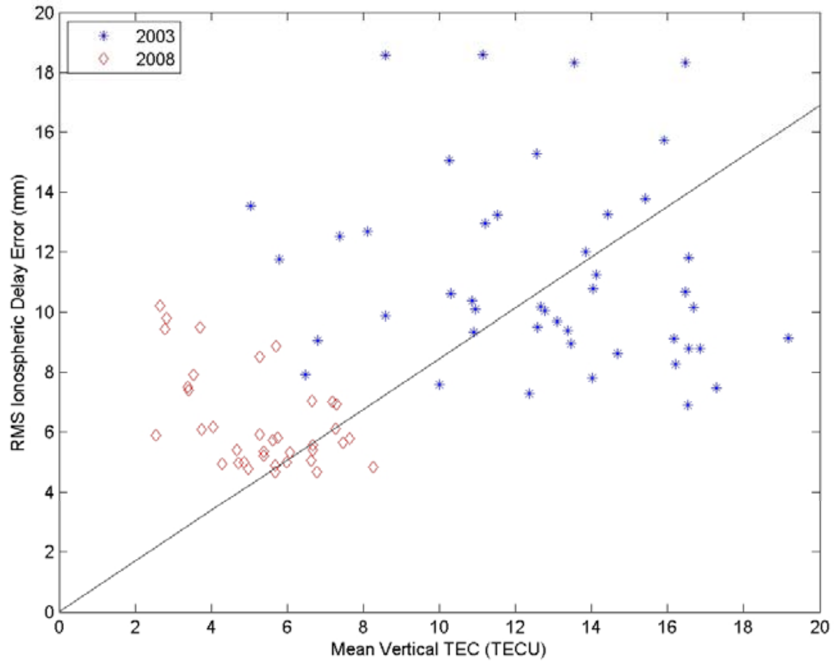
Ionosphere



Ionosphere

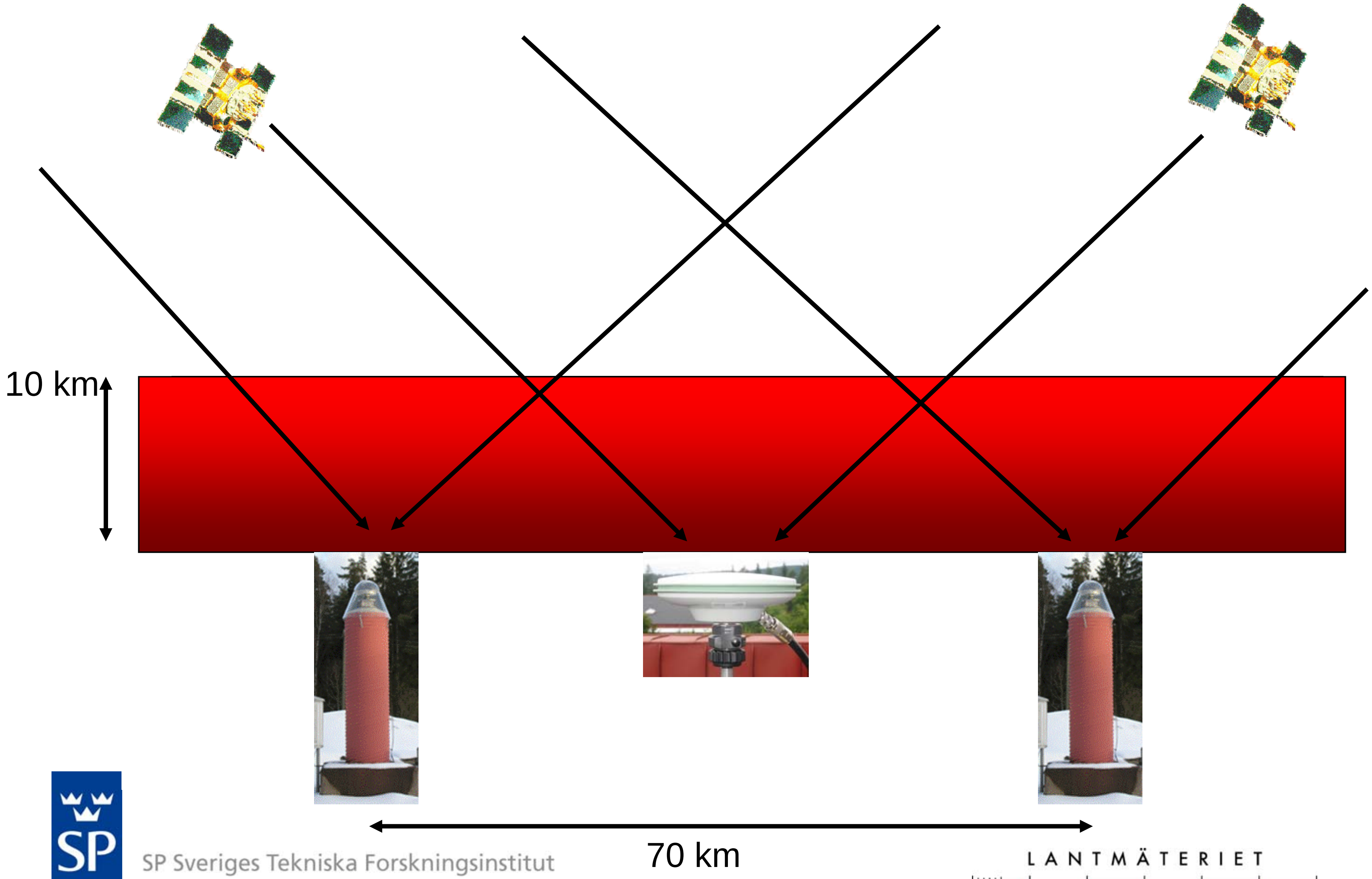


Variation during half a solar cycle

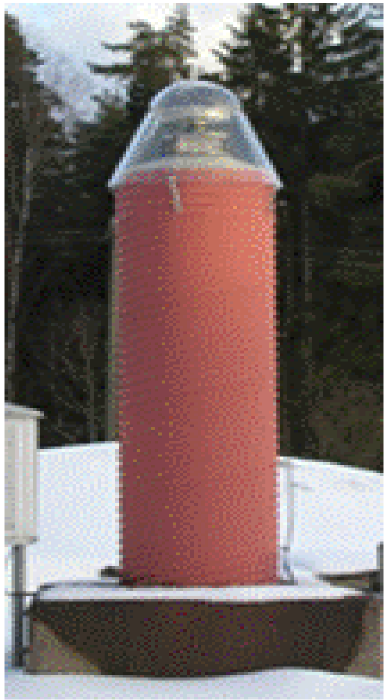


Model for how the value of TEC influence the RTK performance (in a statistical sense)

Troposphere



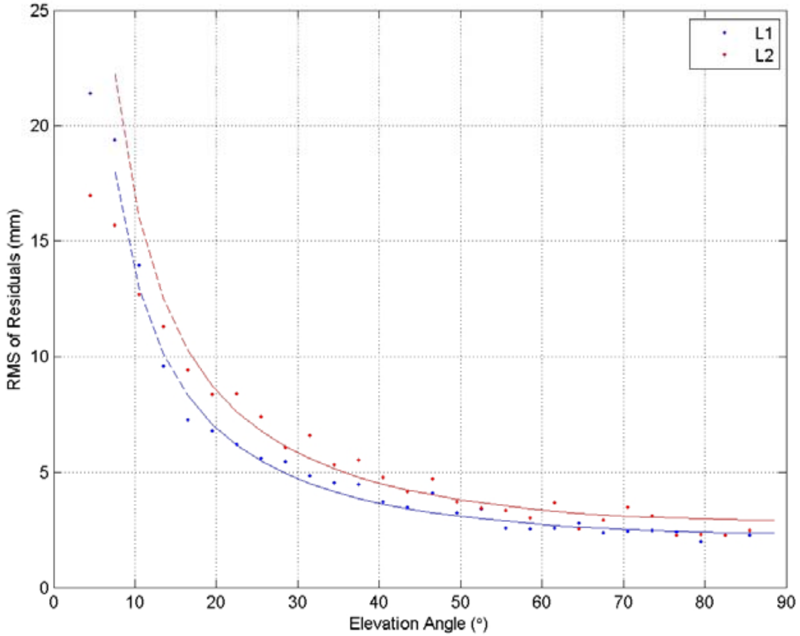
Local effects



Reference station

Rover

Local effects



Experiment

Model

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Error budget - Vertical

Error source		Error Nominal situation (mm)	Error 5% (mm)	Error 95% (mm)
Satellite clocks		0	0	0
Satellite orbits		0	0	0
Ionosphere		16.6	4.3	36.2
Troposphere		20.9	6.4	32.2
Local Effects	Rover	5.5	3.3	11.1
	Reference sites	1.4	1.4	1.4
Total (rms)		27.3	-	-

Error budget - Horisontal

Error source		Error Nominal situation (mm)	Error 5% (mm)	Error 95% (mm)
Satellite clocks		0	0	0
Satellite orbits		0	0	0
Ionosphere		10.7	2.8	23.4
Troposphere		3.9	1.4	7.0
Local Effects	Rover	3.5	2.1	7.0
	Reference sites	0.9	0.9	0.9
Total (rms)		12.0	-	-

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What can we do?

- Combination of observables (L1 or L3 ?)
- Satellite constellation
- Elevation cutoff
- Network density
- Reference network interpolation

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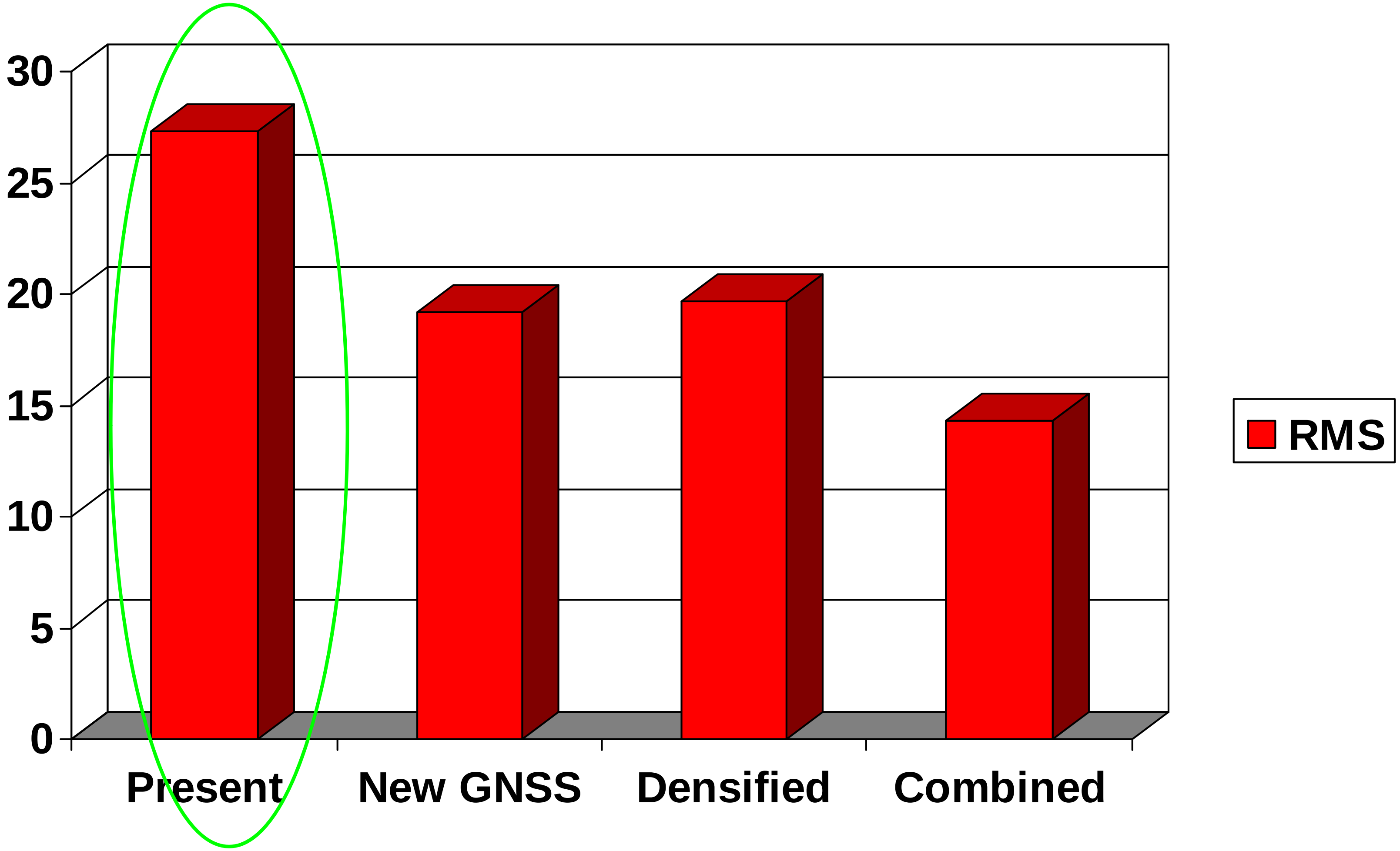
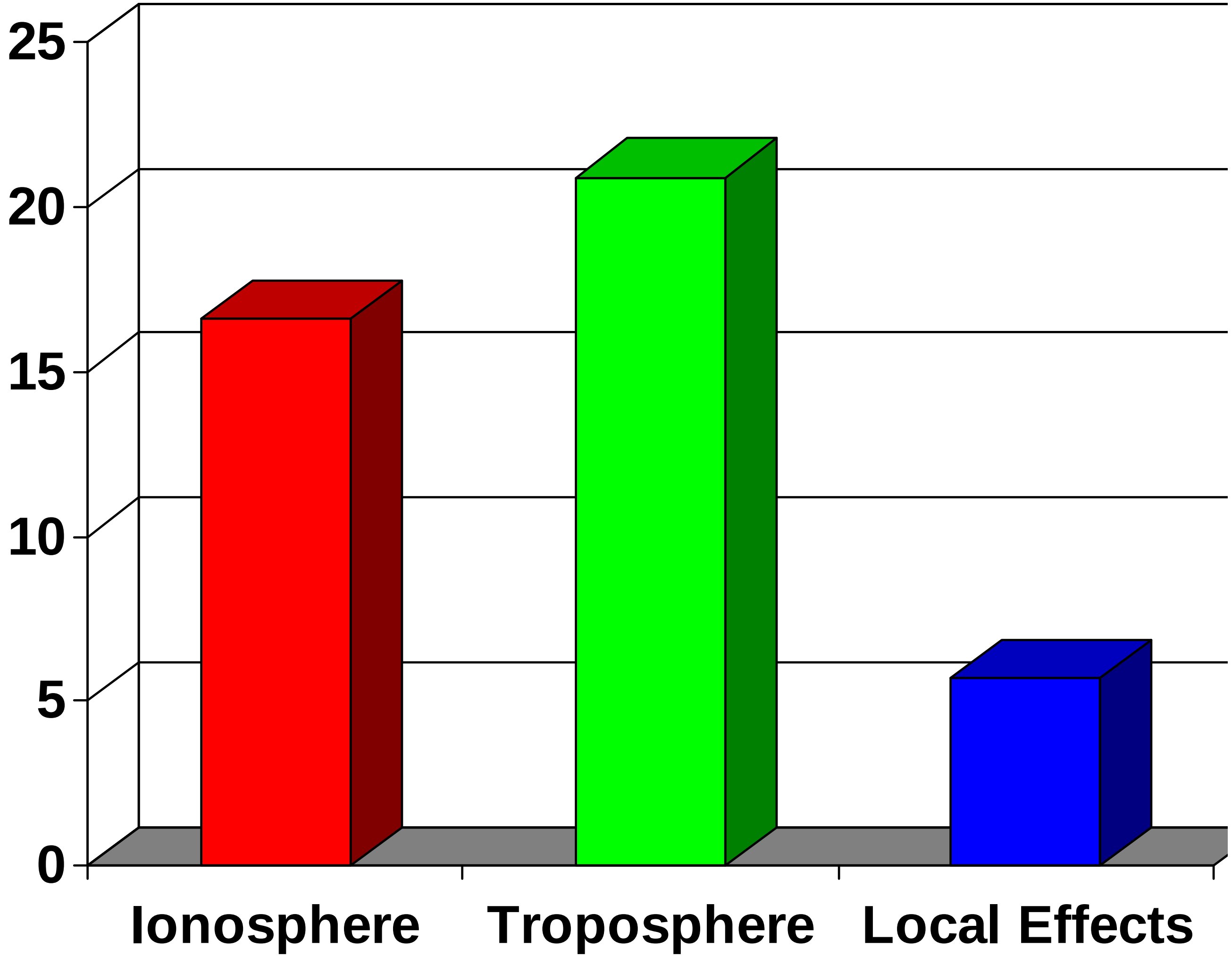
Vertical Error



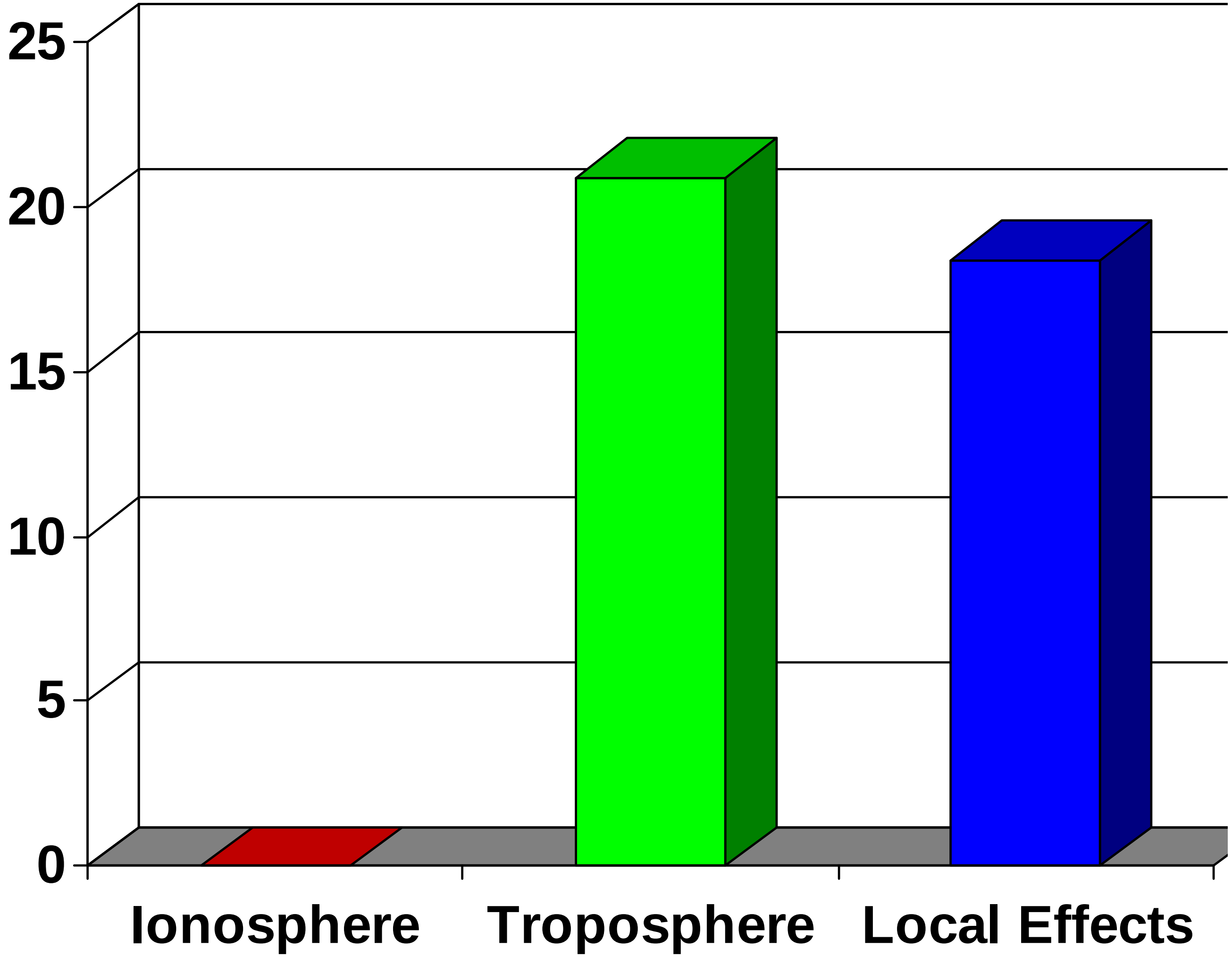
L1 - Processing

Total
27 mm



L3 – Processing (ionosphere free linear combination)

Total
28 mm



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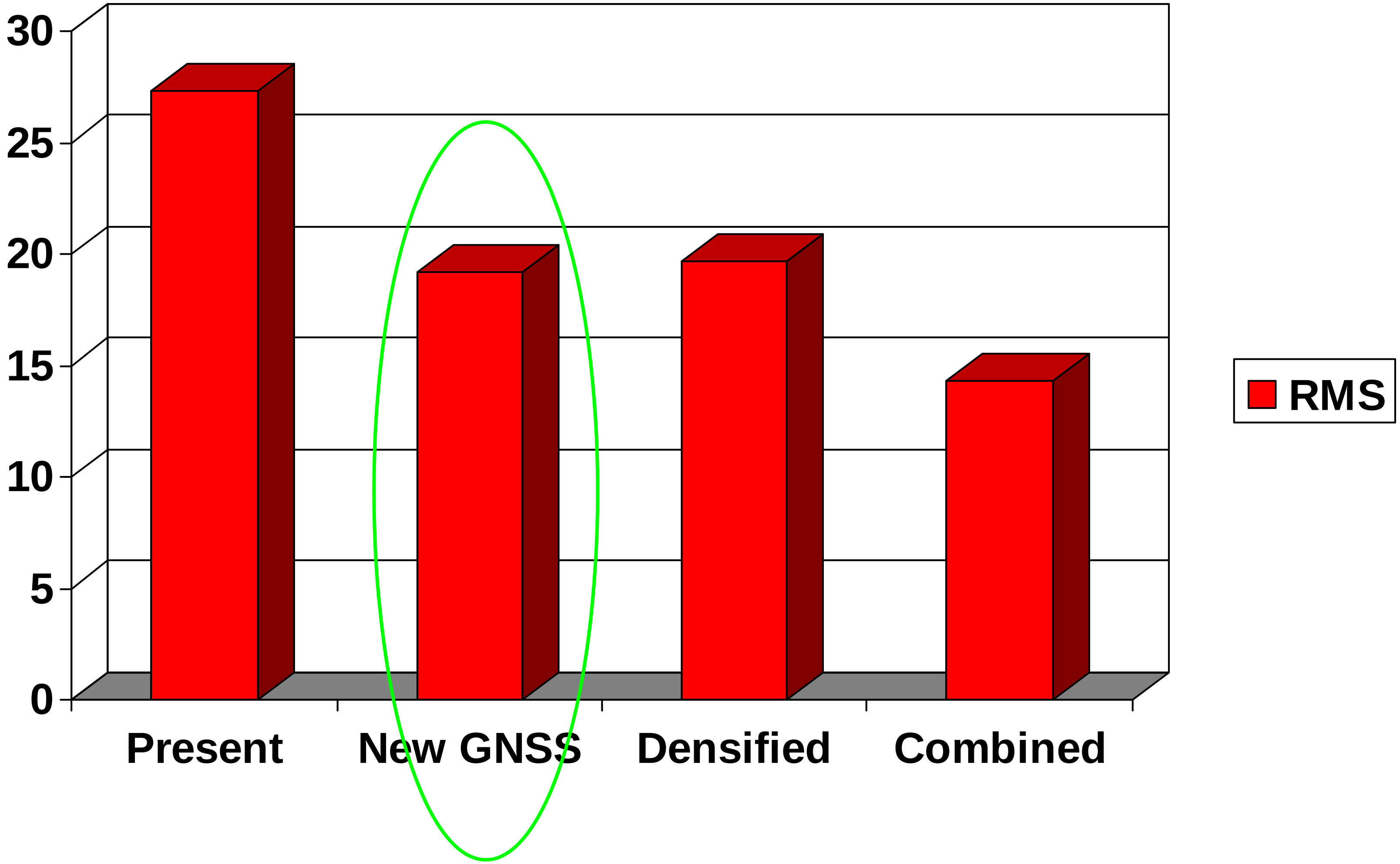
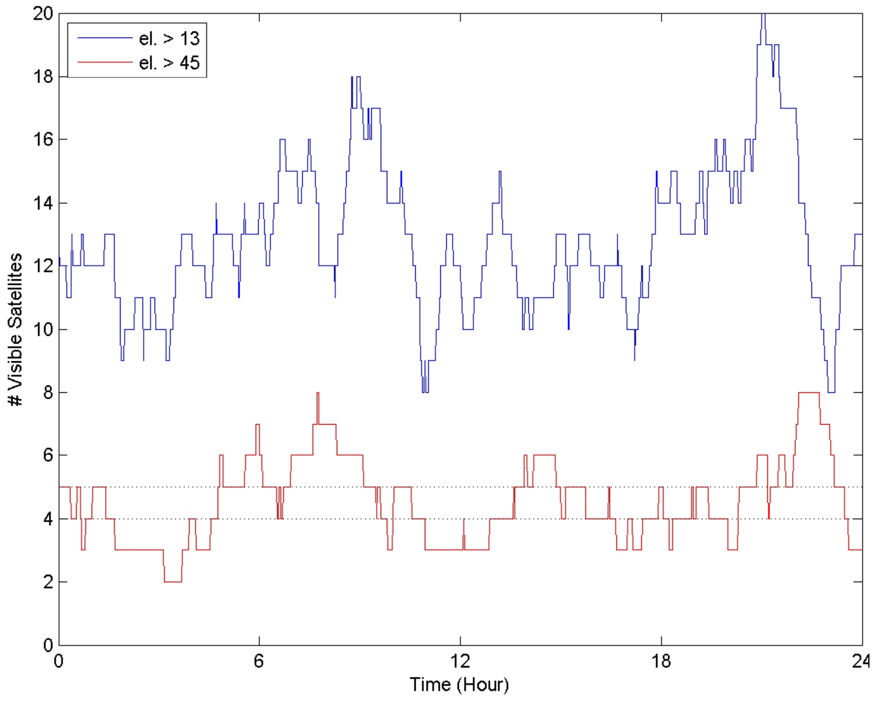
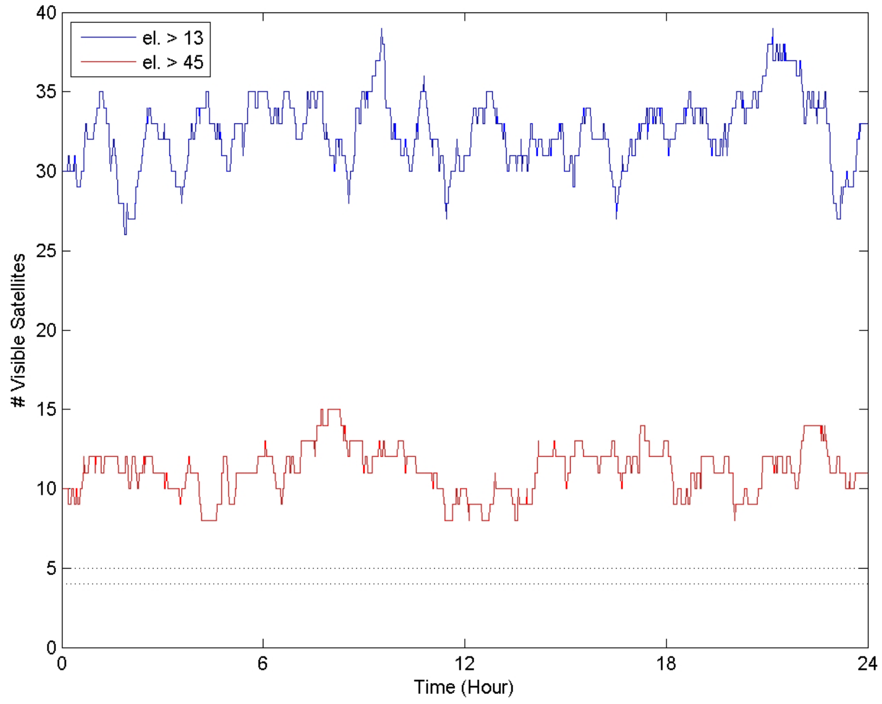
Vertical error



Satellite constellation

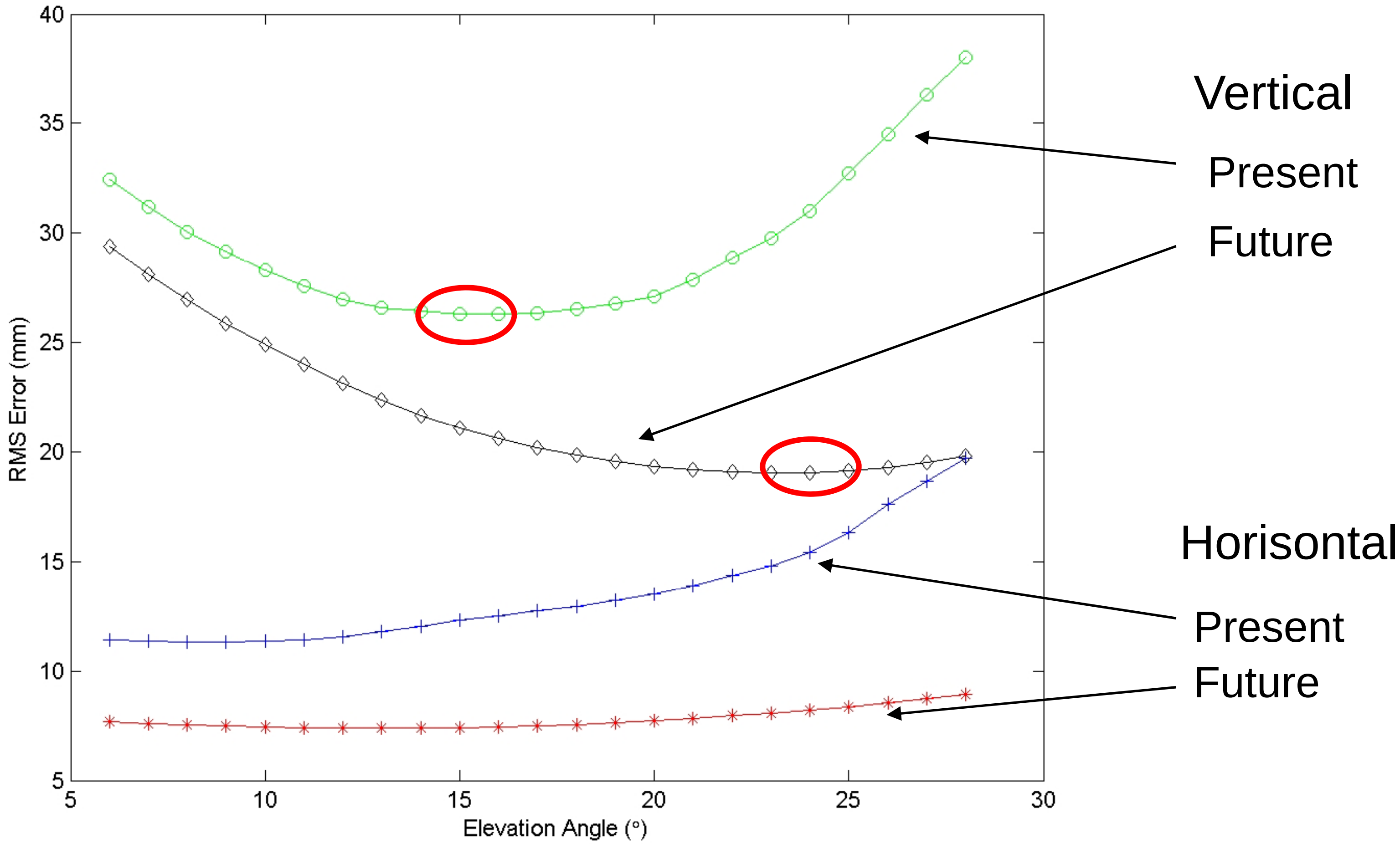




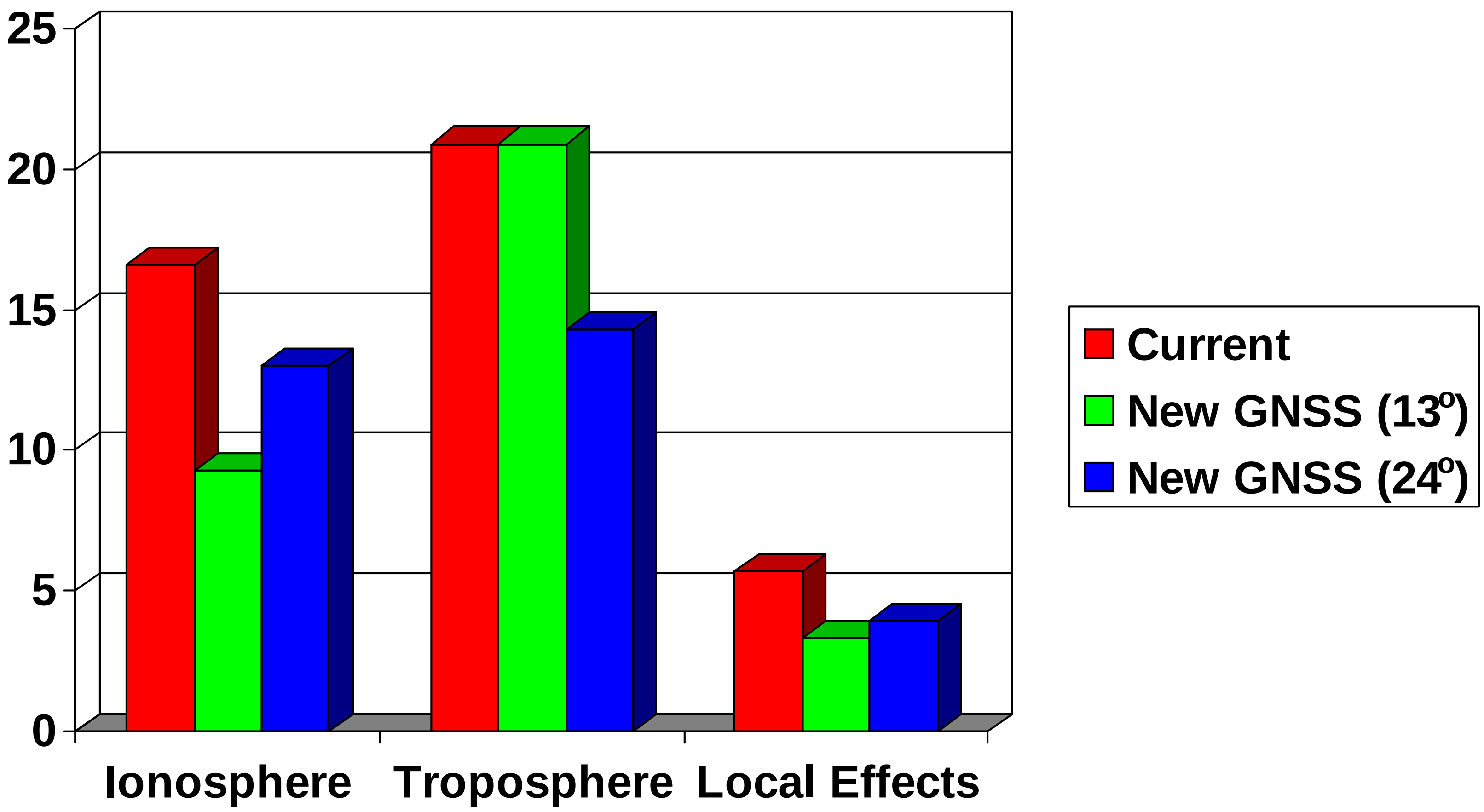
Present (GPS+GLONASS)
8-18 svs > 13° elevation
2-8 svs > 45° elevation

Future (GPS+Glo+Galileo..)
26-38 svs > 13° elevation
8-15 svs > 45° elevation

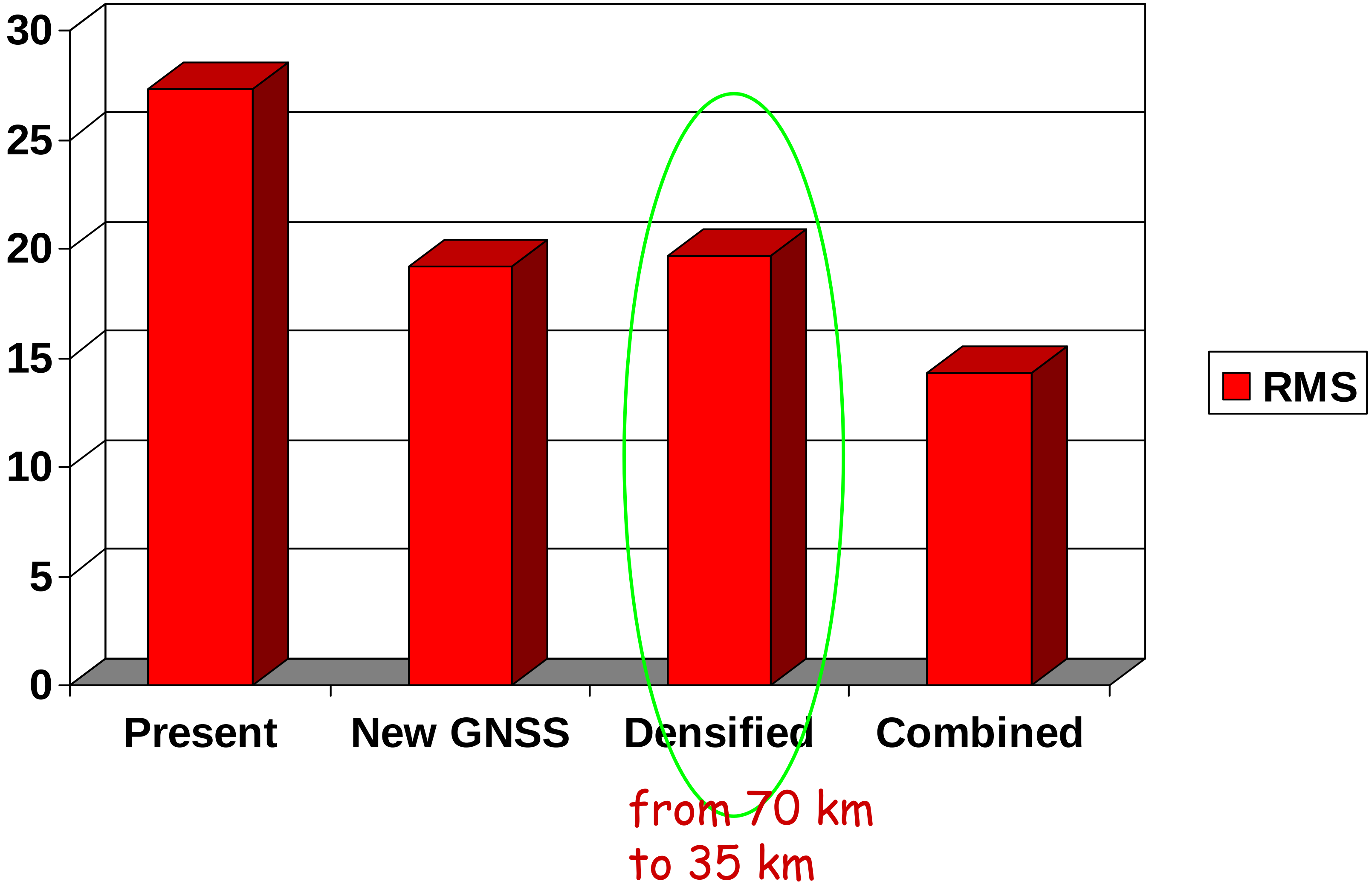
Elevation cutoff



L1 - Processing



Vertical error



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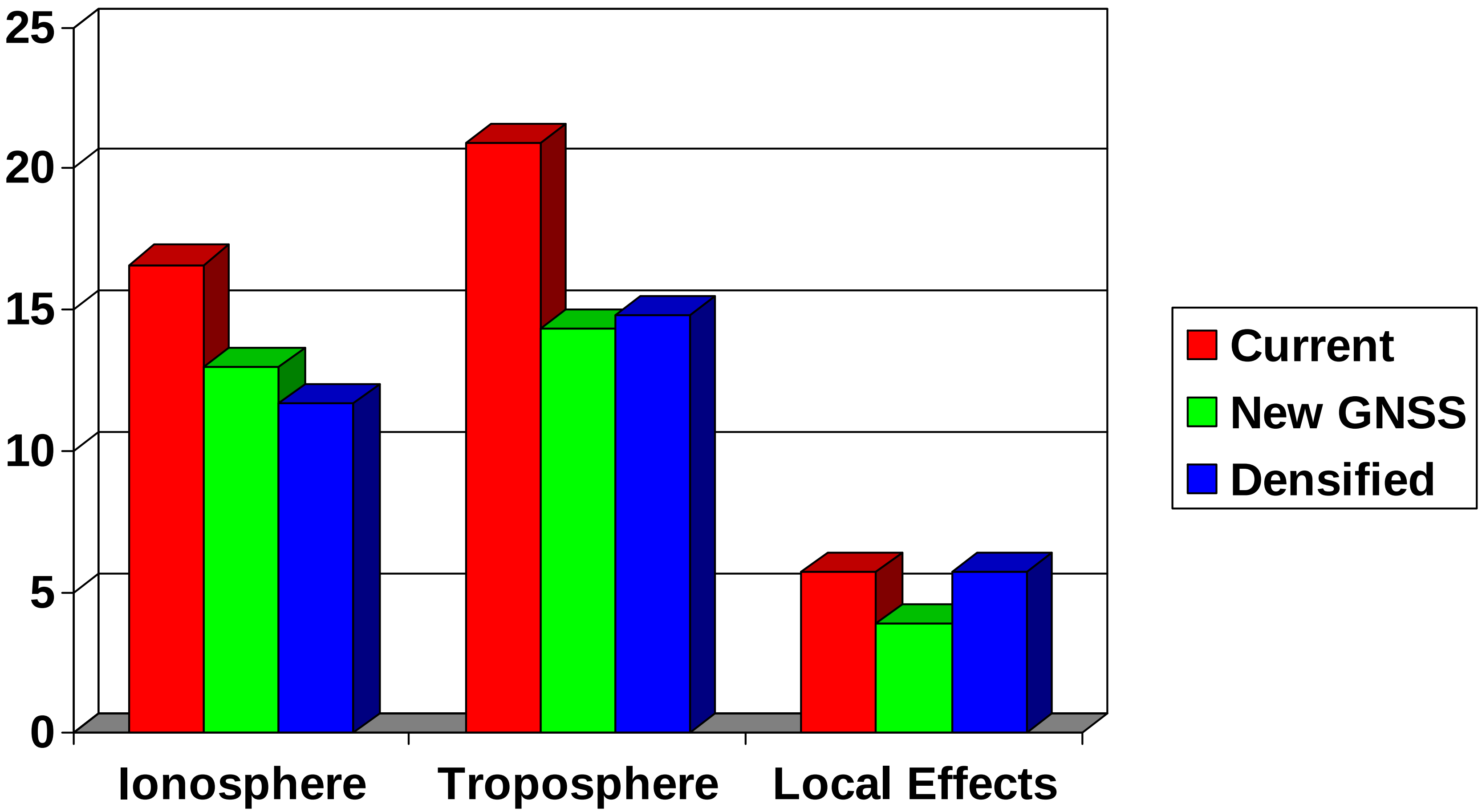
Error Components



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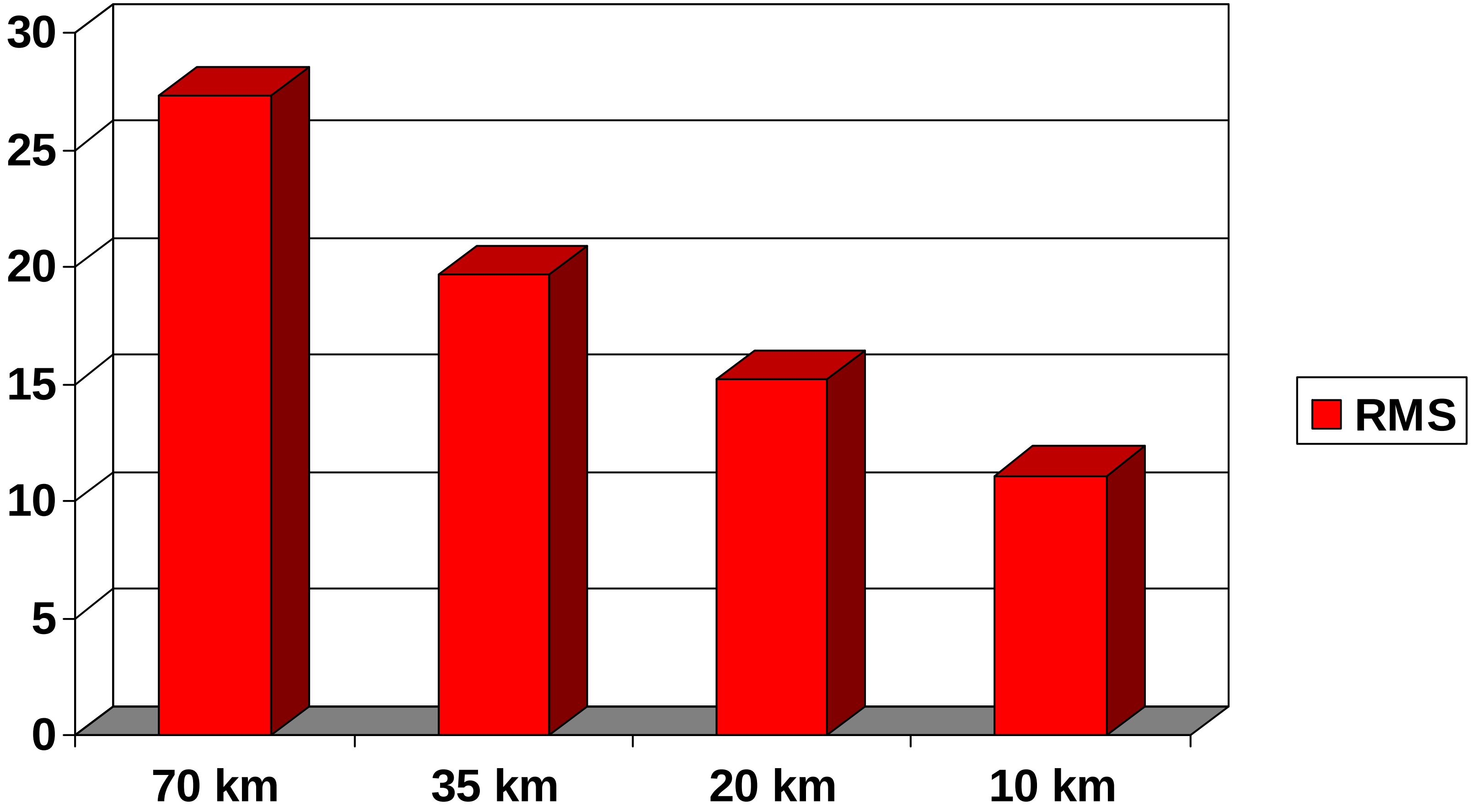
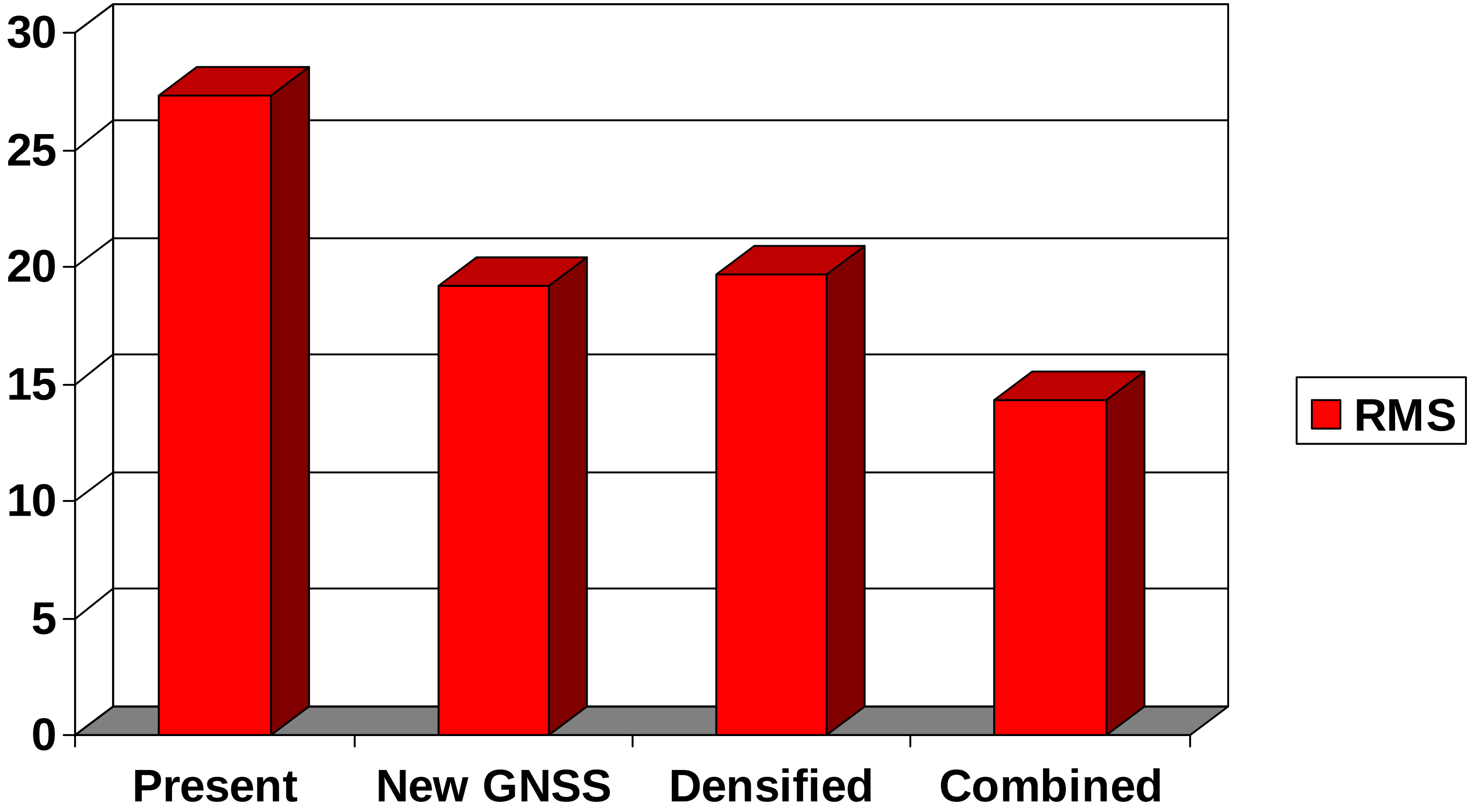
Vertical error – Densification
(current satellite constellation)



Vertical error



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Summary

- The theoretical simulation confirms Empirical values for vertical uncertainty (-network program performs well)
- The Ionosphere is periodically a dominant error source
  - The use of the L3 combination removes these errors at the expense of local effects
- The availability of future systems will reduce the vertical error from 27 mm to 20 mm
  - Future system allows for higher cutoff angle!
- A condensed network (35 km) reduces the vertical error from 27 mm to 20 mm
- The combination of a condensed network (35 km) and new satellite systems will result in a vertical error of 14 mm
- The combination of a condensed network (10 km) and new satellite systems will result in a vertical error of 8 mm