High-Precision GNSS Positioning

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Abstract

High-Precision GNSS positioning results are based on carrier-phase measurements as the primary observables. Accuracies in the range of better than 1 centimetre and up to 1 decimetre can not be achieved with code observations. They require processing of the much more accurate but ambiguous carrier-phase observations. Presently, there are three satellite systems which make signals available for GNSS positioning: the US-American GPS, the partly re-built Russian GLONASS, and the several satellite-based augmentations systems (SBAS) like WAAS, EGNOS, GAGAN and MSAS. High-precision positioning can be achieved in various modes of operation: baseline-based differential positioning in the form of Real-Time Kinematic (RTK), network-based differential positioning in the form of Network-RTK, or Precise Point Positioning (PPP) either in post-processing or in real-time. All techniques have in common that accuracy and reliability increases if observations are performed in static mode. This paper discusses and compares the various techniques of high-precision GNSS positioning and gives an outlook into further improvements expected for the near future.

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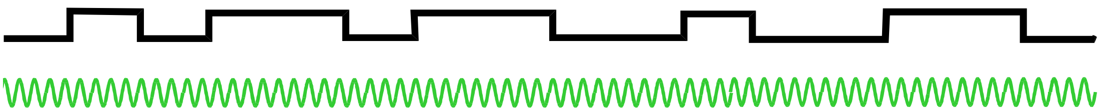
Overview

High-Precision GNSS Positioning

- Carrier-Phase Observations
- Status of GNSS Systems
- Positioning Methods
  - real-time differential: RTK, Network-RTK
  - Precise Point Positioning (PPP)
  - static mode
- Outlook

Code and Carrier-Phase Observations



Observable	Multipath + Noise	Pseudorange
Code	dm … m	unambiguous
Carrier-Phase	mm … cm	ambiguous (dm)

GNSS

GNSS today	GNSS tomorrow
GPS	+ GPS
+ GLONASS	+ GLONASS
+ SBAS	+ Galileo
	+ Compass
	+ SBAS
	+ ...
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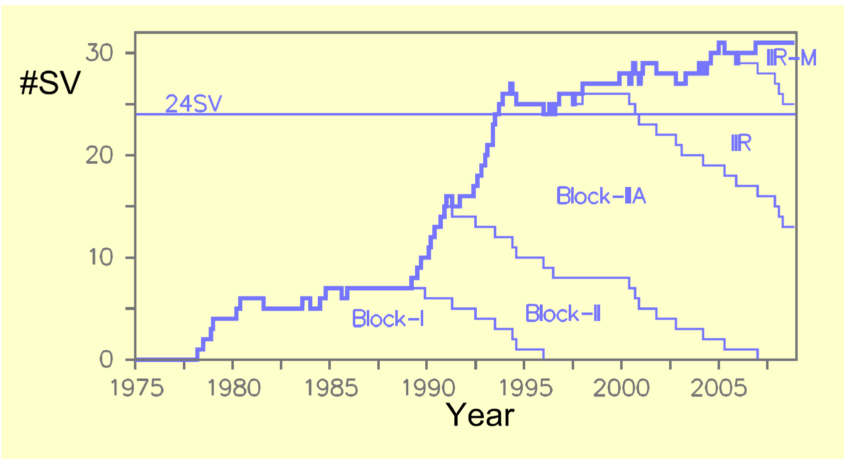
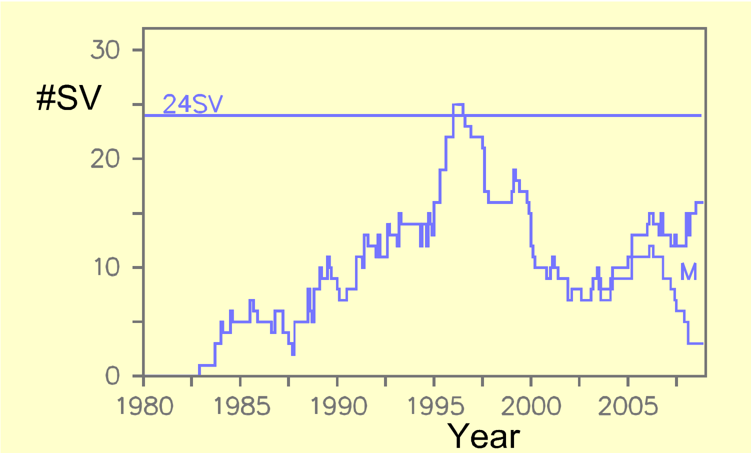
GNSS today	**GNSS tomorrow**

Status of GPS Satellite Segment (August 2008)



Status of GLONASS Satellite Segment (August 2008)



+ 6 SV to be launched in 2008

GLONASS in Comparison to GPS

GPS

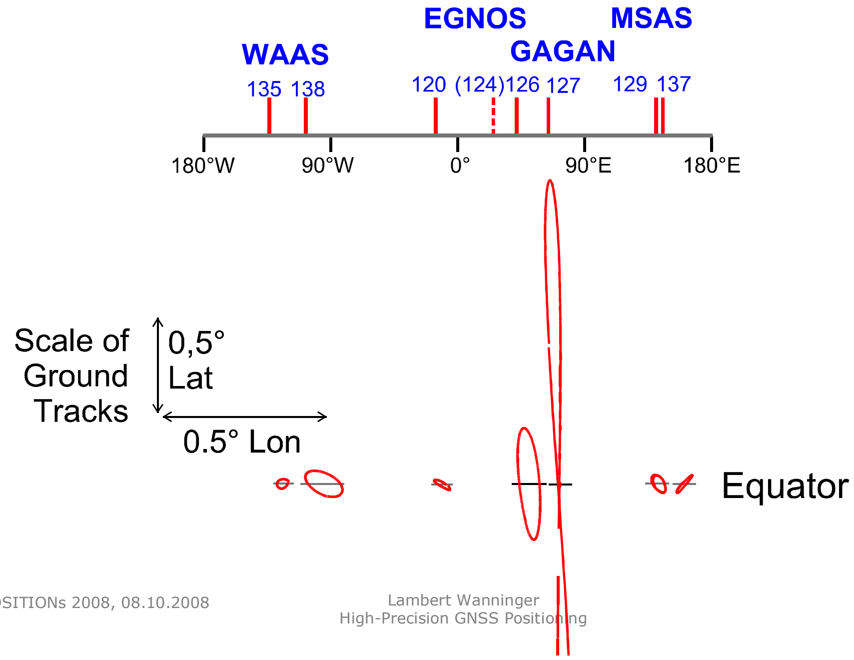
Code Division Multiple Access (**CDMA**):
identical transmitting frequency, individual PRN codes

GLONASS

Frequency Division Multiple Access (**FDMA**):
same PRN-code for all satellites, but individual frequencies

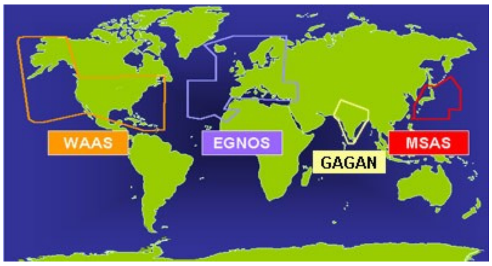
→ **Inter-channel biases,**
which need to be estimated,
complicate ambiguity resolution

SBAS Satellites and their Orbits (March 2008)



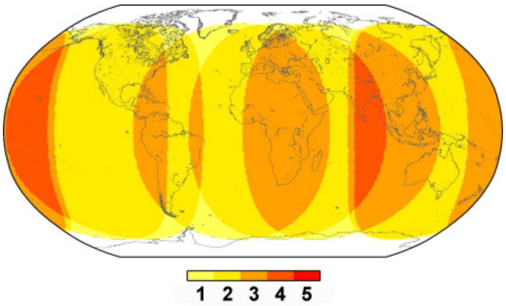
SBAS Coverage (March 2008)

Integrity and DGNSS Service



service areas

Positioning Service



visible satellites (10° elevation mask)

SBAS in Comparison to GPS/GLONASS

GPS/GLONASS

- orbital periods ~ 12 h
- dual-frequency signals

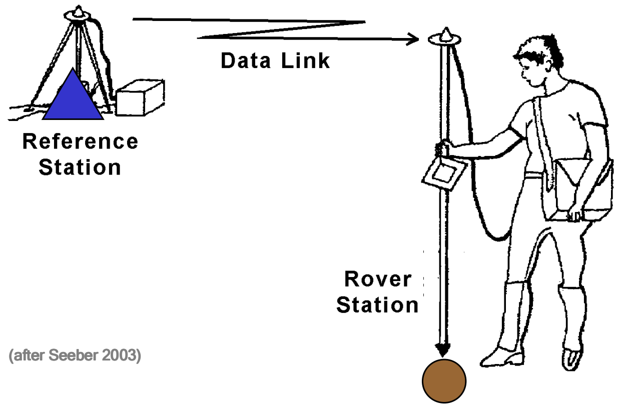
SBAS

- geostationary, (almost) fixed
- presently single-frequency
- signals GPS-like, but less accurate code measurements

RTK

Real-Time Kinematic

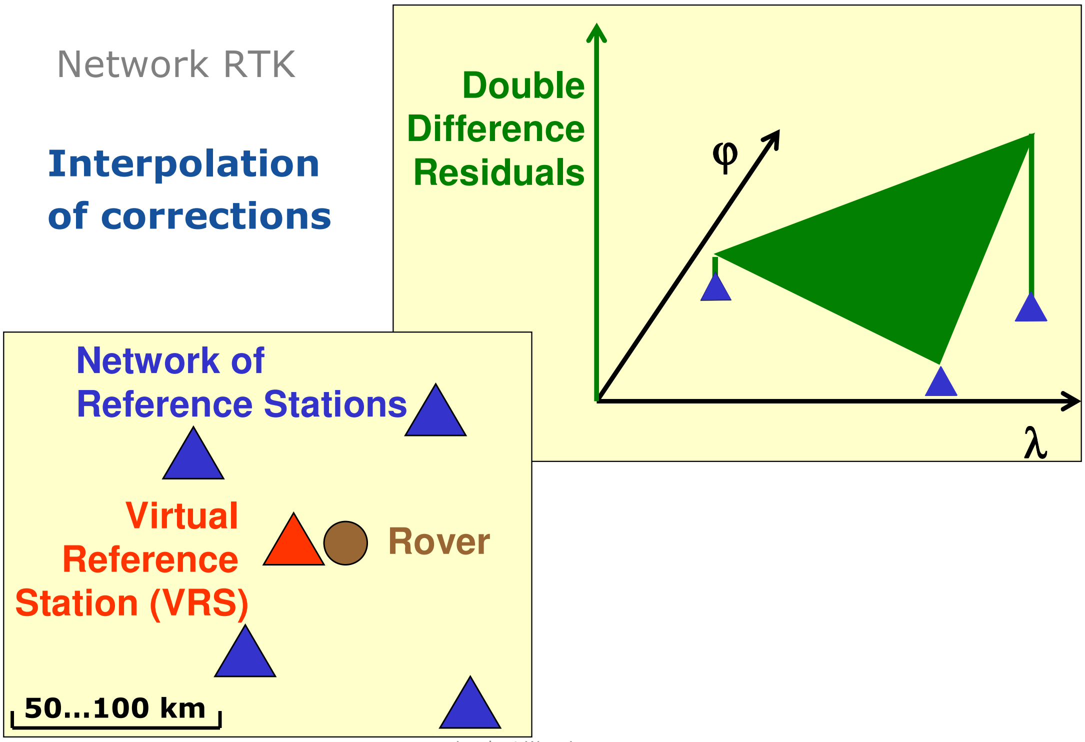
- differential (baseline lengths: … several km)
- carrier-phase primary observable
- ambiguities fixed to integer values



(after Seeber 2003)

Network RTK

Interpolation of corrections

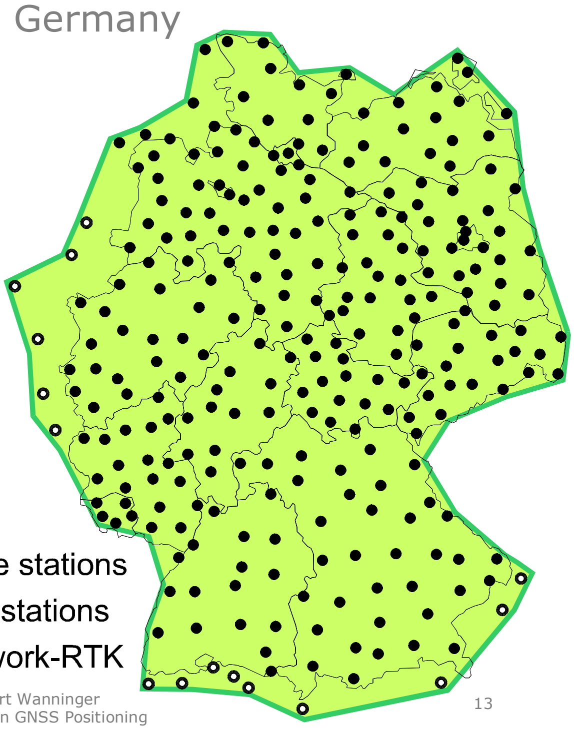


Network RTK Services in Germany

SAPOS

ascos

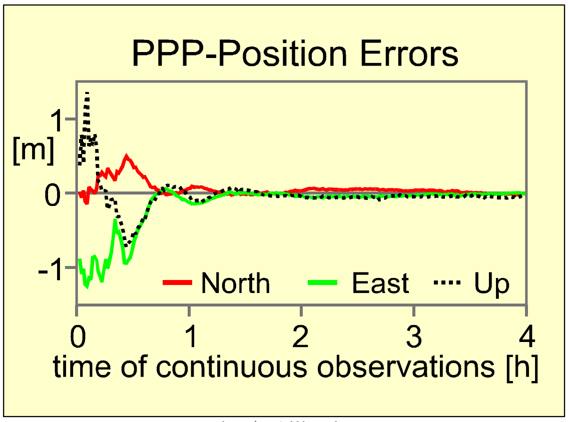
Trimble VRS Now



● SAPOS reference stations
○ further reference stations
service area network-RTK

Precise Point Positioning (PPP)

- absolute positioning
- use of precise satellite orbits and clock corrections
- continuous carrier-phase observations
- usually no ambiguity fixing
  → *float*-solution, **convergence time**



Precise Point Positioning (PPP)

Post-Mission Processing

Orbits and clocks by the Internat. GNSS Service (IGS), time delay of at least ~1 day, free of charge

→ **CSRS-PPP Service**:
online-service for automized data processing,
free of charge

Real-Time Processing

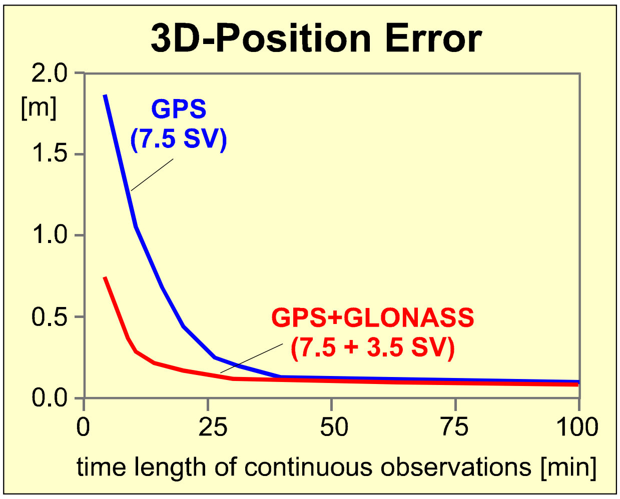
real-time orbits and clocks, by NASA's Jet Propulsion Lab

→**Commercial service** by StarFire (NavCom Tech.), distribution by comm. sat.s

Precise Point Positioning (PPP)

Convergence Time

tremendous decrease if more satellite signals are available



Precise Point Positioning (PPP)

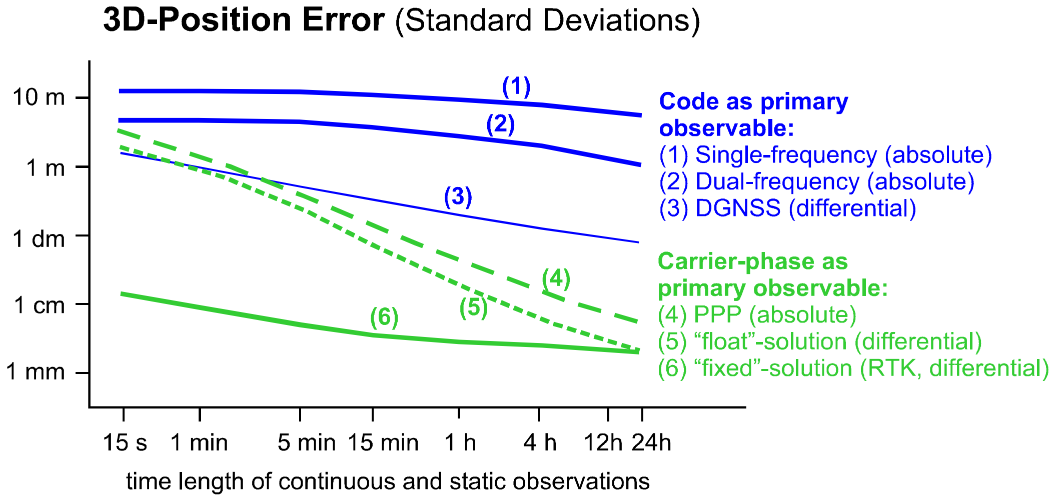
Achievable Accuracies horizontal/vertical

as a function of time of continuous carrier-phase observations

	Kinematic		Static
1 h	0.10/0.15		0.05/0.10
4 h	0.03/0.05	[m]	0.02/0.04
24 h	0.03/0.05		0.01/0.02

Static Mode

Increase in accuracy for long-term continuous and static observations



Outlook High-Precision GNSS

Expected improvements in satellite systems and in signals

- re-completion of GLONASS satellite segment
- GPS-L2C
- GPS-L5
- SBAS-L5
- GLONASS CDMA-signals
- GLONASS-L3
- Galileo

→ many more satellites+signals, more accurate code meas.

High-precision GNSS: faster, higher availability, more reliable, more accurate