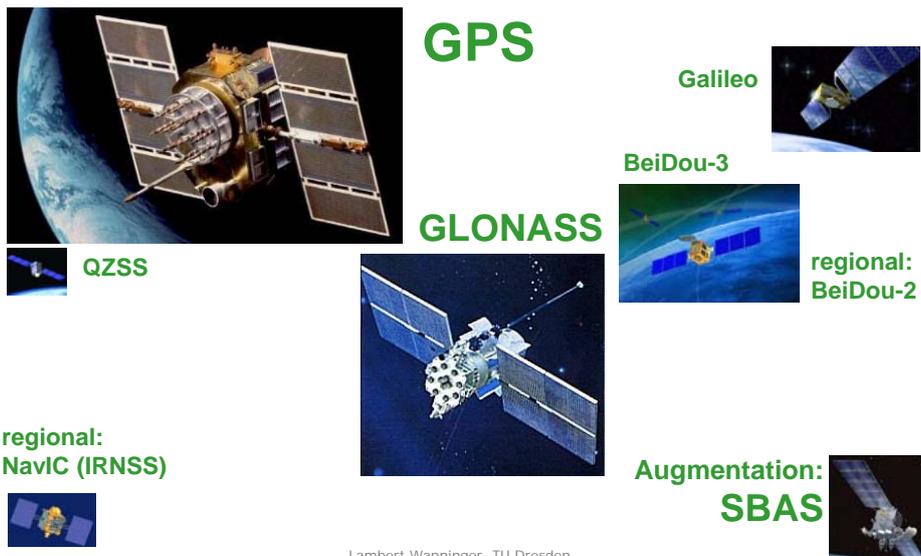


State-of-the-art of cm-accurate real-time GNSS positioning

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Global Navigation Satellite Systems (GNSS)



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Overview / Keywords

Code based positioning

Carrier-phase based positioning

Ambiguity fixing

Real-time models/corrections

Local ionosphere corrections

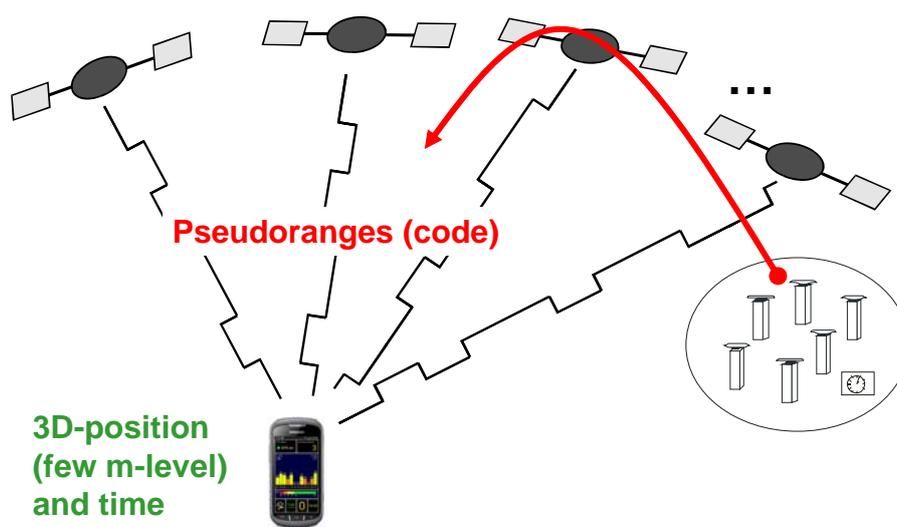


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Standard Positioning Service

GNSS



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Code observations + add. information → position

satellite positions
satellite clock corrections
global ionosphere model

predicted data

1 m to few m accurate → code
10 bps / satellite

→ GNSS

(corrections to) satellite positions
(corrections to) sat. clock corr.
regional ionosphere model

real-time information

few dm to 1 m accurate → code
200 bps

→ WADGNSS (SBAS)

code corrections

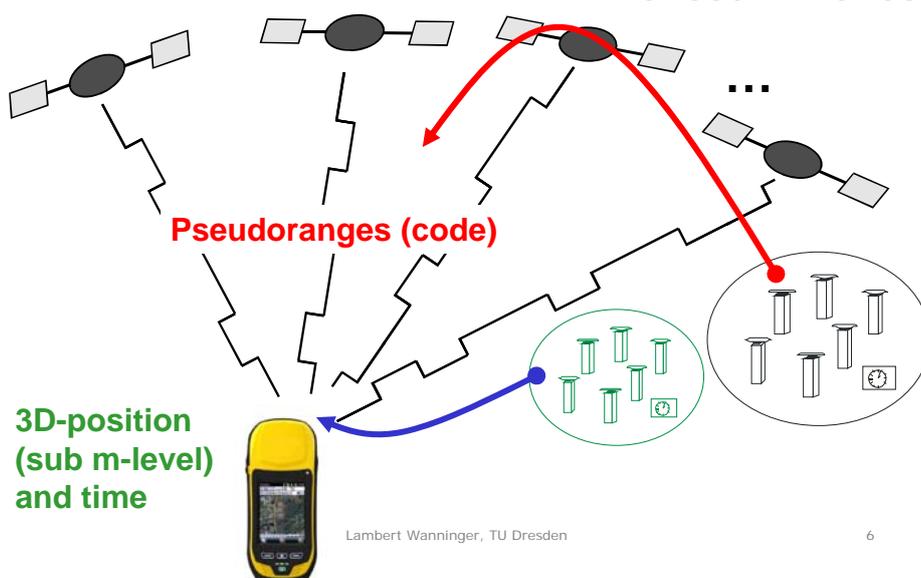
→ DGNS

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Submeter-level Code-based Positioning

DGNSS / WADGNSS



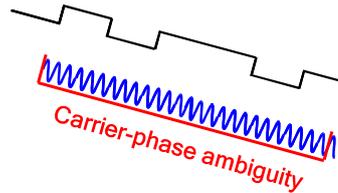
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GNSS Observables

signals from GNSS satellites → pseudorange observations

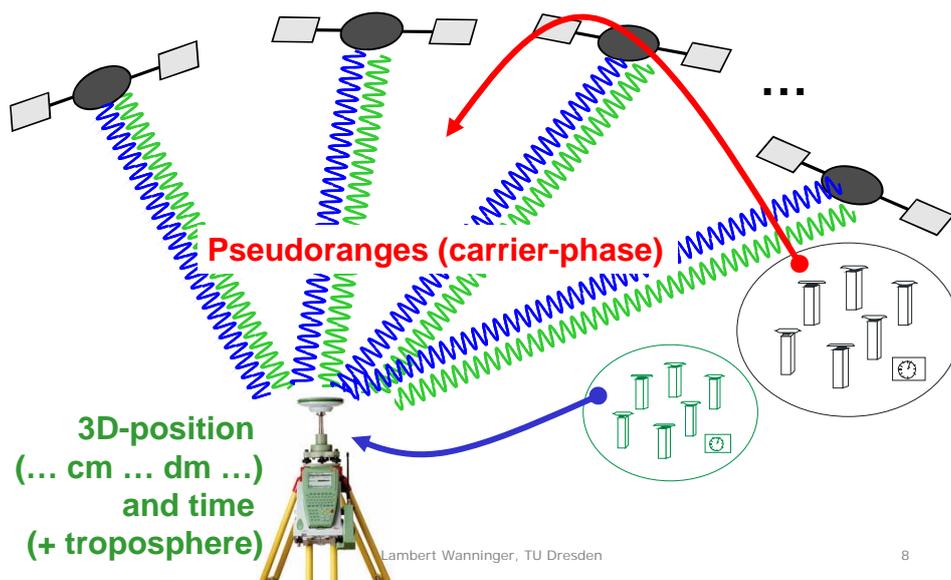
code (modulation): **dm ... m**
phase (carrier): **mm ... cm**
Doppler (carrier)
S/N



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Cm-accurate GNSS Positioning



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Phase observations + add. information → position

1 cm to few cm accurate → carrier-phase

real-time information

(corrections to) satellite positions
(corrections to) sat. clock corr.

→ PPP (float)

+ Fractional Cycle Biases (FCB)

→ PPP (fixed)

+ local ionosphere corrections

→ PPP-RTK / RTK-PPP

+ local troposphere corrections

1000-2000+ bps

carrier-phase corrections

→ RTK / Network-RTK

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Cm-accurate GNSS Positioning

Precise Point Positioning (PPP)

PPP (float): no ambiguity fixing → long convergence periods (hours)

PPP (fixed): ambiguity fixing without local information:
convergence periods of at least many minutes

PPP-RTK: with local information: fast ambiguity fixing,
cm-accuracy within many seconds

RTK / Network-RTK

local information → fast ambiguity fixing, cm-accuracy

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PPP Ambiguity Fixing **w/o** Iono. Corrections

Requires ionosphere-free linear combinations

(1) Melbourne-Wübbena linear combinations

Widelane Phase: wavelength 75 ... 97 cm

Narrowlane Code: low noise level

→ Widelane ambiguity fixing

(2) ionosphere-free linear combination of phases

with wavelengths of ~ 11 cm

→ PPP (fixed)

but long convergence periods

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Ambiguity Fixing **with** Precise Iono. Corrections

Ionosphere corrections from local reference station/s

Second frequency ...

... not necessary for ionosphere corrections,

... can be fully used for improvement of ambiguity fixing

Wavelengths	widelane	75 ... 97 cm
	extra widelane	... ~ 170 cm

→ RTK, Network-RTK, PPP-RTK

short convergence periods

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Cm-accurate GNSS Positioning

RTK	Network-RTK	PPP-RTK
local UHF radio	regional GPRS/UMTS	global / regional satellite link
mostly with user owned reference station	governmental or commercial services	e.g. Trimble CenterPoint RTX QZSS-CLAS

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Trimble CenterPoint RTX

Global network of reference stations → **PPP(fixed)**
+
Regional network of reference stations
→ iono. (+ tropo.) corrections → **PPP-RTK**

Satellite communication link: ~ 2400 bps

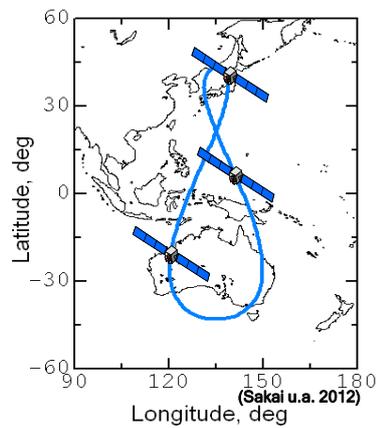
Accuracy < 4 cm (horizontal, 95 %)

Initialization Time:



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OZSS – Quasi-Zenith Satellite System



GPS-like signals

→ additional pseudorange observations

real-time augmentation inform.

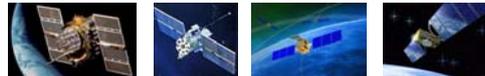
SLAS: 250 bps → WADGNSS, code

CLAS: 2000 bps → PPP-RTK, phase

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Summary



cm-accurate GNSS positioning

Requires

- carrier-phase observations
- real-time corrections: satellite orbits/clock corrections
- real-time corrections: ionospheric refraction

Various realizations

- RTK
- Network-RTK
- (PPP) / PPP-RTK

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