Institut für Erdmessung

Leibniz Universität Hannover

A Virtual Receiver Concept for Continuous GNSS based Navigation of Inland Vessels

- **NAVITEC 2018 • ESA/ESTEC • Noordwijk** -

Session: Precise Positioning

Tobias Kersten, Le Ren and Steffen Schön | Thursday, December 6th, 2018

Motivation • Inland Vessel Transport

Inland Waterway Transport (IWT)

- reliable, almost safe, eco-friendly and profoundly effective
- reducing traffic stress on rail and motorways
- future: combined transport (rail, waterway, motorway, regional & local)

Present transport vessel navigation

- precise navigation by GNSS in real-time kinematic RTK mode
- requires mobile data infrastructures / interfaces (RTCM, NTRIP, OSR/SSR)
- navigation precision required / available: 2-5 cm / ≈dm

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Uelzen (GER): Skipper died
cabin and steel cable collides
as vessel entered lock


Surwold/Emsland (GER): Vessel collides with bridge
skipper died
thick fog possibly the cause
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1,5t

Virtual Receiver (VR) for Inland Waterway Transport

Scientific key questions

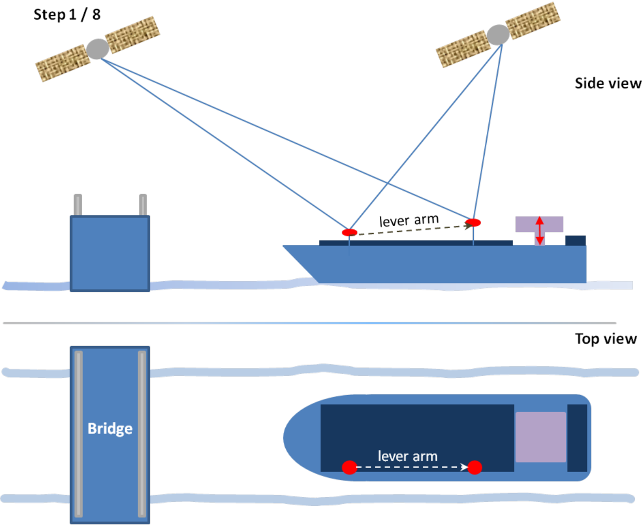
- safety relevant applications (e.g. collision security, driver assistance) require high accuracy (carrier phase)
- carrier phase & code observables affected by discontinuities, interruptions or complete loss-of-lock
- evaluating benefits for **code based navigation** (combining receiver antennas, assisting/aiding carrier phase ambiguity resolution)

Virtual Receiver - observation domain

- provides enlarged field of view (individual antennas)
- usable on arbitrary rigid navigation platform (satellite, aircraft, ferry, vessel)[a]
- requires lever arm definition (accurate and precise)

[a] Kube et al. (2018, 2012); Schön and Alpers (2018); Kersten et al. (2018)

Concept - Virtual Receiver (VR)



Concept - Virtual Receiver (VR)

Virtual Receiver - position domain

- **input** observables from individual receiver antennas
- **position** solution - robust by strengthened satellite geometry
- **angles** transport rate (specific approach for inland vessels)
- **synchronisation** coordinate observations of individual antenna locations

Specifications to present approach

- cost effective no Inertial Navigation System (INS)
- heading consider transport rate (in-situ by moving baseline)

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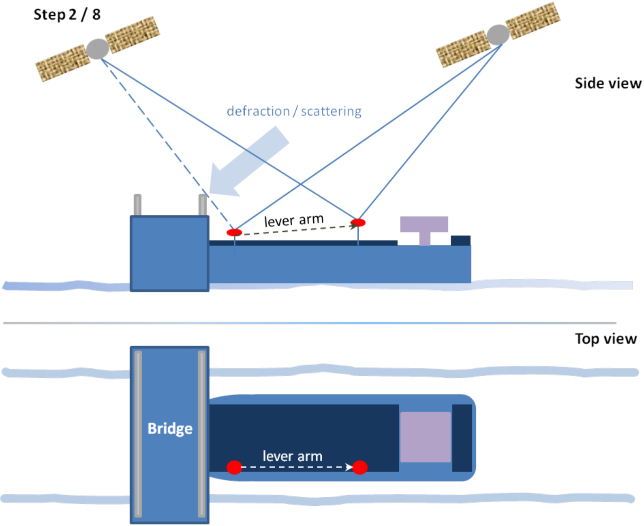

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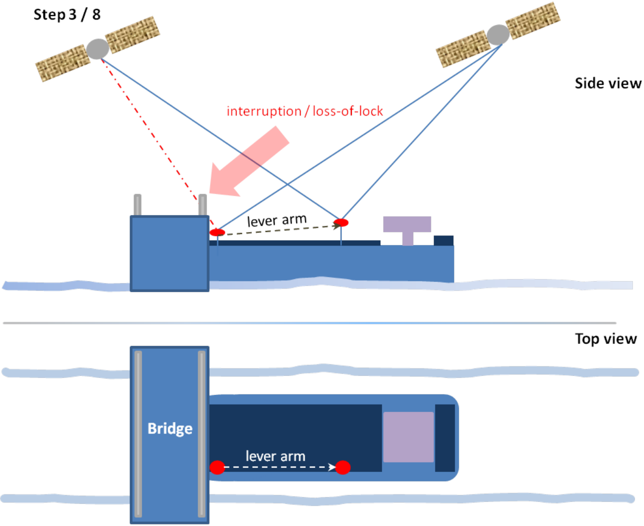

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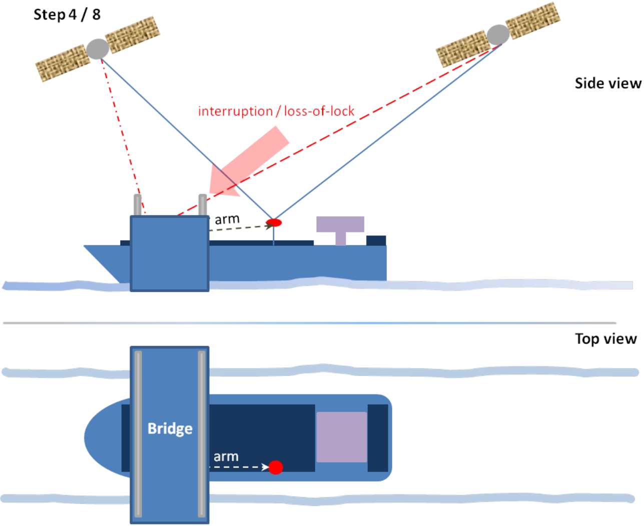

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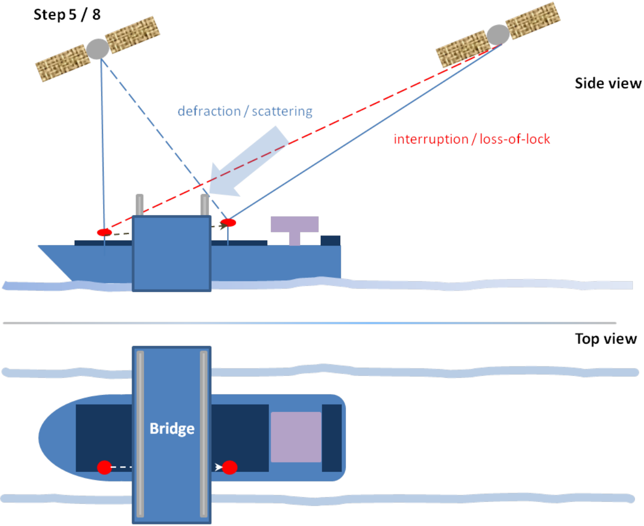

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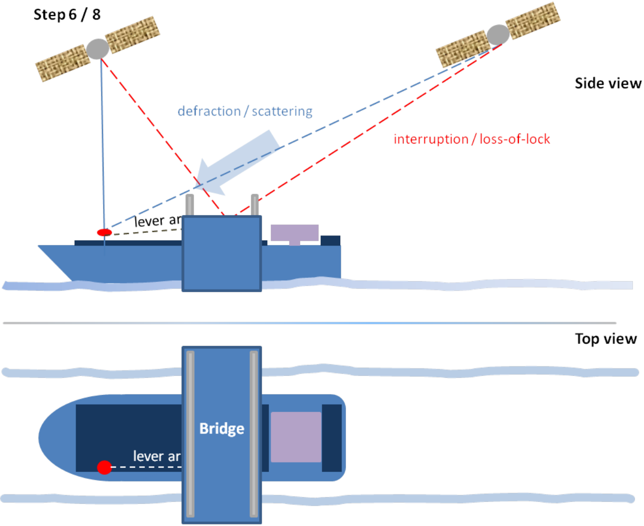

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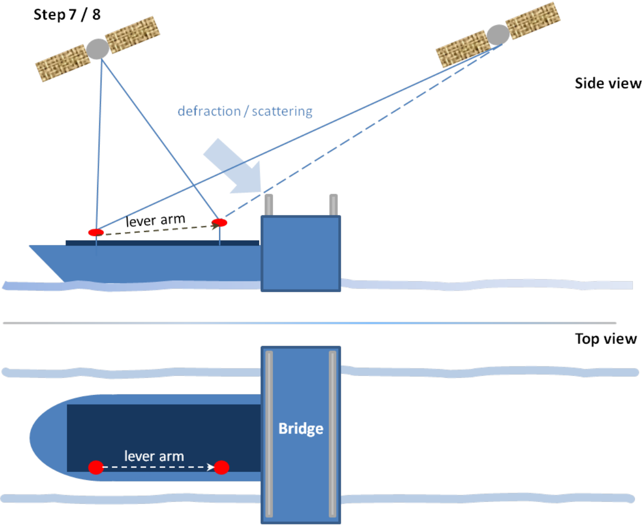

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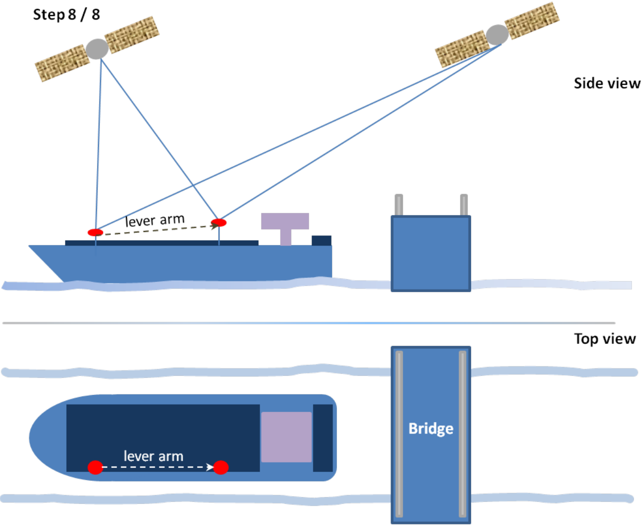

Dedicated studies - the vessel *MS Jenny*

Kersten et al. (2018)

MS Jenny

- overall geometry: 100 m length, 9.5 m width, 3.16 m depth
- two GNSS units alongside the vessel at bow (FRNT) and stern (BACK)
- datasets recorded in summer 2016 and 2018 (under investigation)
  - **static**: mooring point Hannover, duration 1 hour (Kersten et al., 2018)
  - **kinematic**: trip westward from Hannover, duration 2.5 hours

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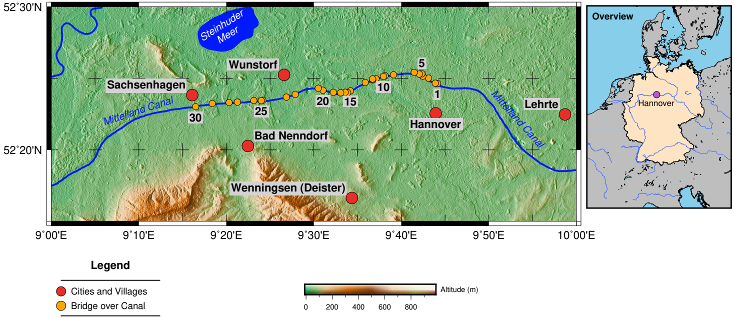
Dedicated studies - trajectory for investigations

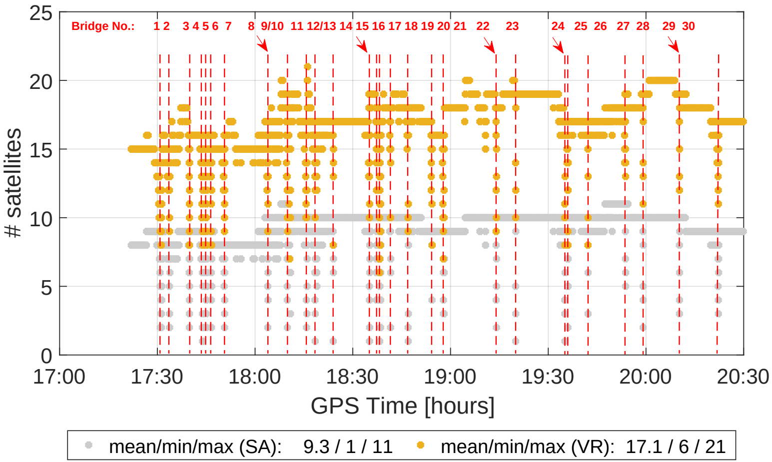


Kersten et al. (2018)

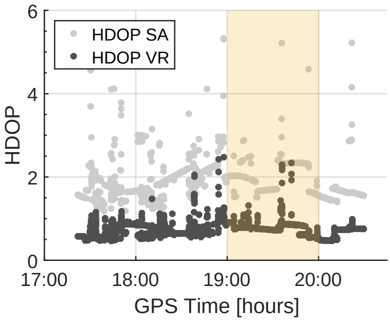
Experimental set-up

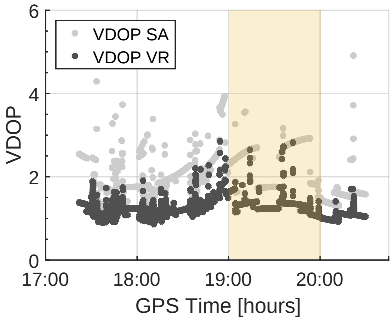
- sessions in 2016 (*static* and *kinematic*) investigated
- reference trajectory (double difference, phase based, NRCan and GrafNav)
- lever arm (FRNT - BACK) by tachymetre and RTK (57.346 m$\pm$2 cm)

Satellite visibility - kinematic session



Code observables: position accuracy I - kinematic session

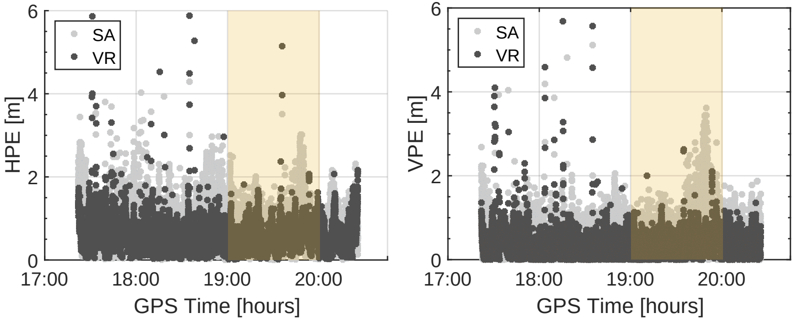




Findings for Virtual Receiver concept

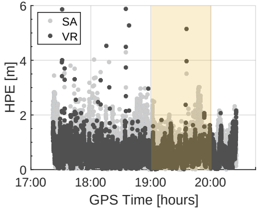
- advantageous to strengthen the satellite geometry
- significant improvements for both, HDOP and VDOP

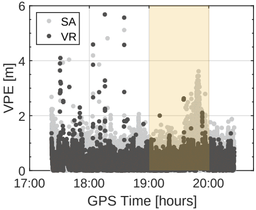
Code observables: position accuracy II - kinematic session



Results

Code observables: position accuracy II - kinematic session

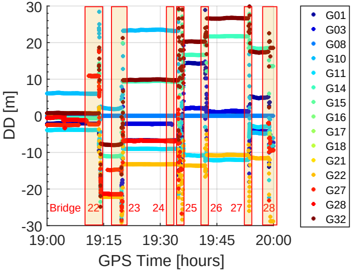




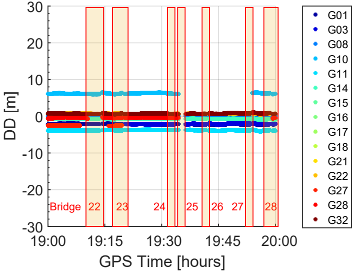
Results

- **static session**
  - available epochs: 100% (VR) and 99.9% (SA)
  - HPE/VPE (VR): **0.70 m / 0.46 m** HPE/VPE (SA): **1.02 m / 0.54 m**
- **kinematic session**
  - available epochs: **94.5% (VR)** and **76.7% (SA)**
  - HPE/VPE (VR): **0.68 m / 0.48 m** HPE/VPE (SA): **0.97 m / 0.71 m**

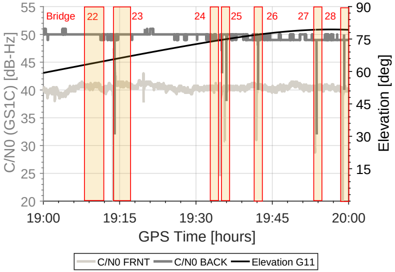
Impact on carrier phases - kinematic session



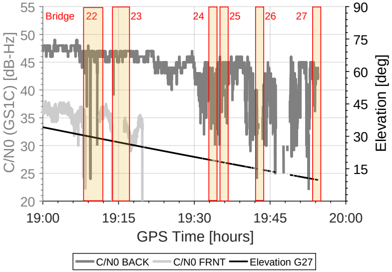
(a) cycle slips in double differences



(b) repaired double differences

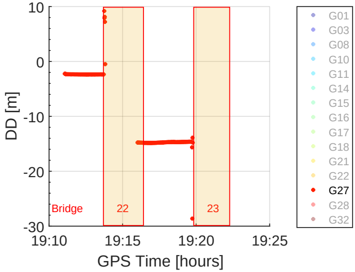


(c) GPS satellite G11



(d) GPS satellite G27

Impact on carrier phases - kinematic session - GPS G27



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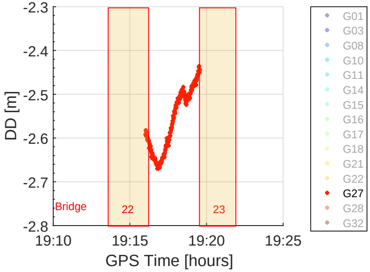
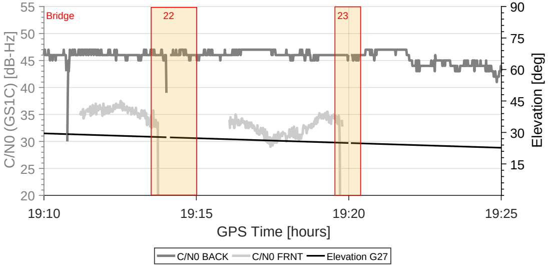


(b) repaired double differences



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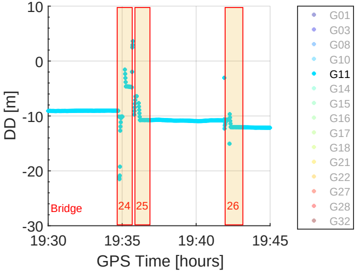

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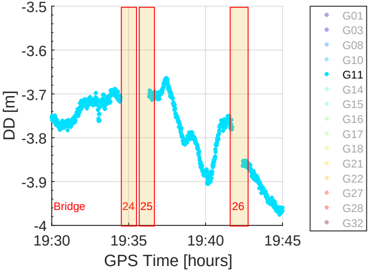

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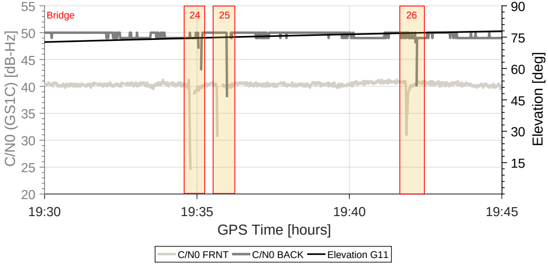

(c) GPS satellite G11

Summary and outlook

Summary

- concept of **Virtual Receiver** approach presented, which strengthens the satellite visibility / navigation geometry by up to **50%**
- code-position accuracy (**13-16%**) improved
- number of epochs with valid solution (**94% (VR)**, **77% (SA)**) improved

Outlook and further work

- promising approach to avoid faults of the carrier phase ambiguity resolution due to enhanced observation continuity (ambiguity bridging)
- receiver clock modelling with chip scaled atomic clocks (CSACs) looks promising to derive reliable positions with special focus on the height component (Krawinkel and Schön, 2018)
- identify bridge (e.g. building structure) by characteristics of GNSS signal distortion

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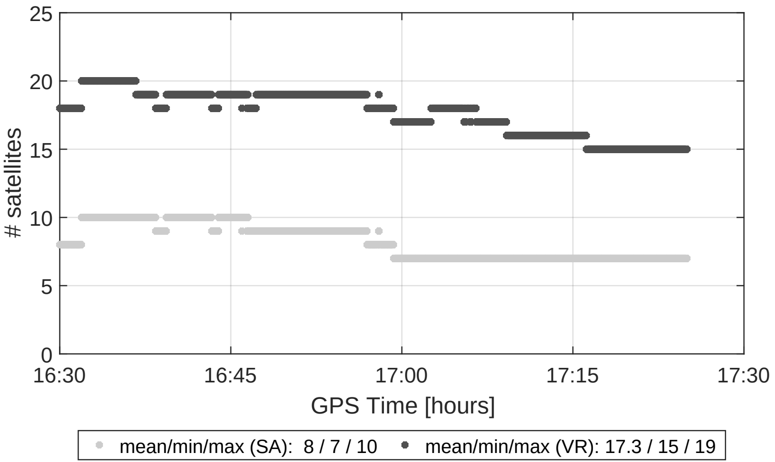
Satellite visibility - static session



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