PRECISE POINT POSITIONING USING COMBDINE GPS/GLONASS MEASUREMENTS

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Outline

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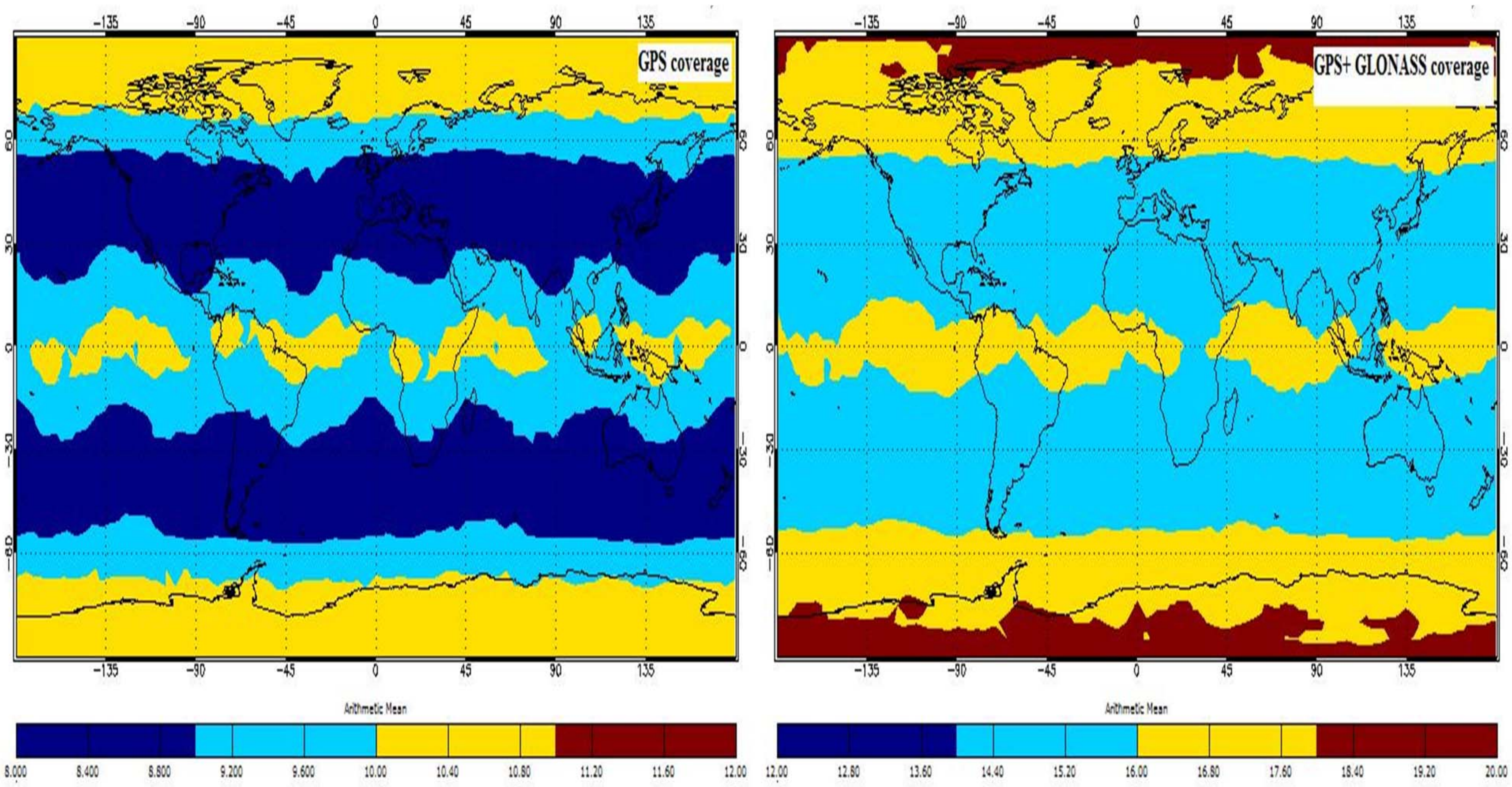
- System’s availability.
- Modeling and processing.
- Estimation of System Time Difference.
- PPP Results and Analysis.
- Conclusions.

Introduction

- Unfortunately, even with the modernized GPS system, there exist situations where the GPS signal may be partially obstructed, which in turn affect the availability and reliability of the PPP solution.
- GLONASS has been gradually replenished since 2002 and has reached a total of 22 operational modernized satellites
- To improve the availability, positioning accuracy and reliability of the PPP solution, we propose to combine the GPS and GLONASS constellations.

System's Availability

Satellite coverage map for November 9, 2010.



M3 the global coverage map for GPS-only and combined GPS/GLONASS constellations. It can be seen that the number of observed satellites increased by 4 to 8 satellites with an average of 60% for the whole world.

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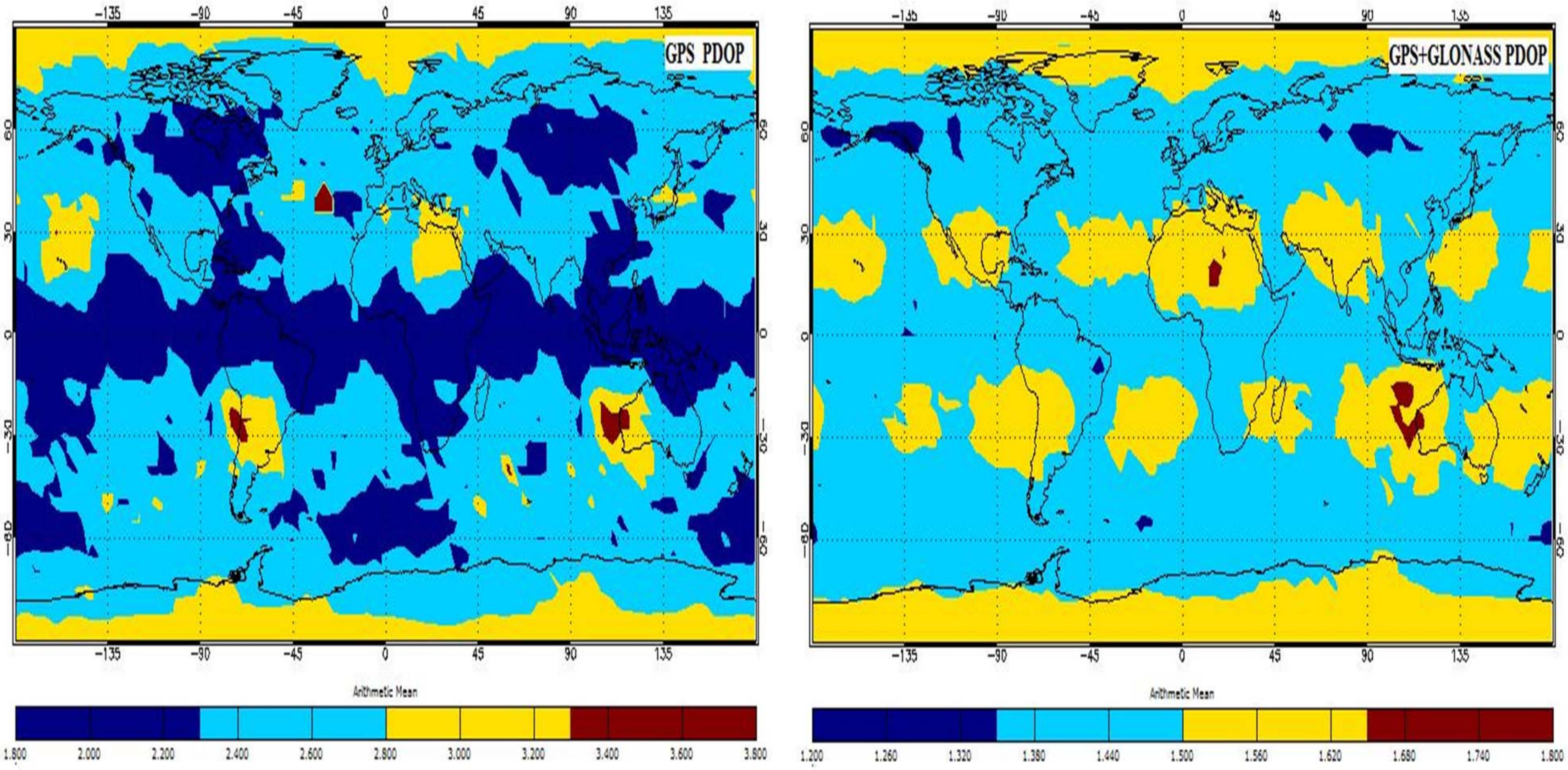
System’s Availability (Cont’d)

M4

PDOP map for November 9, 2010.



M4 Global PDOP map shows that adding GLONASS constellation to GPS constellation improves the PDOP values between 30% at mid-latitudes, below 60o, and 60% at high-latitude, with minimum global PDOP of 1.2 in comparison with 1.8 for GPS-only constellation.
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Modeling and Processing

Combined GPS/GLONASS PPP model were developed to process combined GPS/GLONASS data. The simplified ionosphere-free observation equations, after applying the precise satellite orbit and clock corrections, can be writen as:

$$P_{IF} = \rho + c.dt + c.dt_{sys} + d_{trop} + \varepsilon_{P_{IF}}$$

$$\phi_{IF} = \rho + c.dt + +c.dt_{sys} + d_{trop} + N_{IF} + \varepsilon_{\phi_{IF}}$$

Where:

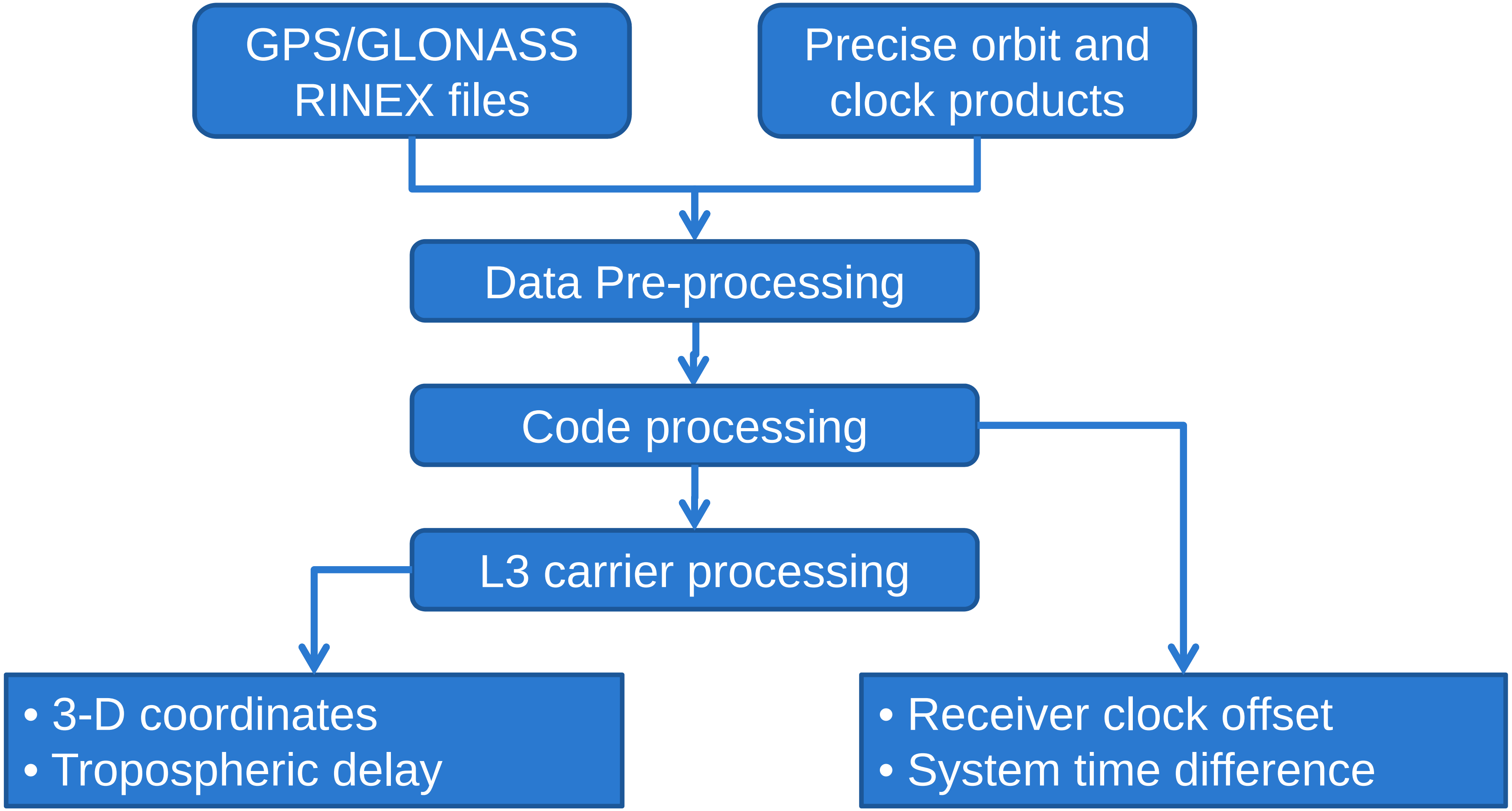
P: the ionosphere-free combination of pseudorange measurements (m);
ϕ : the ionosphere-free combination of carrier-phase measurements (m);
ρ : the geometric range between satellite and receiver (m);
c: the vacuum speed of light; is the tropospheric delay;
dt: the receiver clock offset with respect to the GPS reference time scale;
dt_{sys}: the system time difference, (= 0 in case of GPS measurements);
d_{trop}: the tropospheric delay (m);
N_{IF}: the combined ionospher-free ambiguity term (m);
ε_{IF}: contains measurement noise, multipath, and other errors.

Modeling and Processing (Cont'd)

- For combined GPS/ GLONASS observation model, two receiver clock offsets are estimated as unknowns, one with respect to the GPS and the other with respect to GLONASS.
- The GLONASS clock offset is expressed as the sum of GPS offset and the system time difference between GPS and GLONASS dt_{sys}.
- Unfortunately, because there are no available calibrated values for the hardware delay of GLONASS receivers, difference between the GPS/GLONASS hardware delay will be included in the estimated system time difference dt_{sys}.
- the hydrostatic (dry) component of the tropospheric path delay is first modelled using the DRY_NIELL model then the troposphere zenith path delay (ZPD) correction including the wet component is estimated at 2 hours interval using the Wet-Niell mapping function.

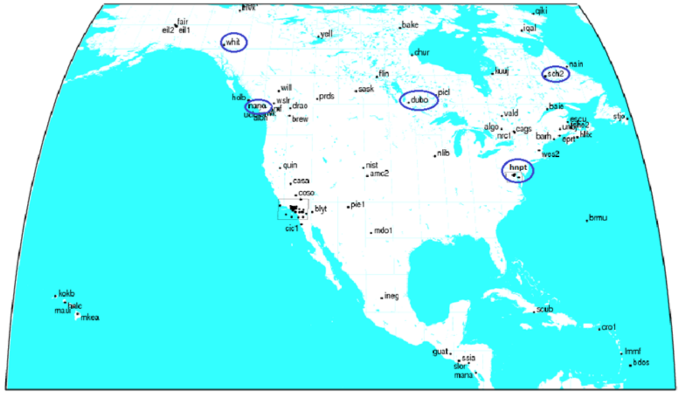
Modeling and Processing (Cont'd)

PPP processing scheme



Modeling and Processing (Cont'd)

- Data sets from five IGS tracking stations across North America were acquired for November 9, 2010.



- Precise orbits and clocks products were obtained from the European Space Agency (ESA).

- Differential code bias (DCB), IERS2000 sub daily pole model, and IAU2000 nutation model were obtained from CODE center.

- Chalmer ocean loading corrections were obtained from the Onsala Space Observatory.

Modeling and Processing (Cont’d)

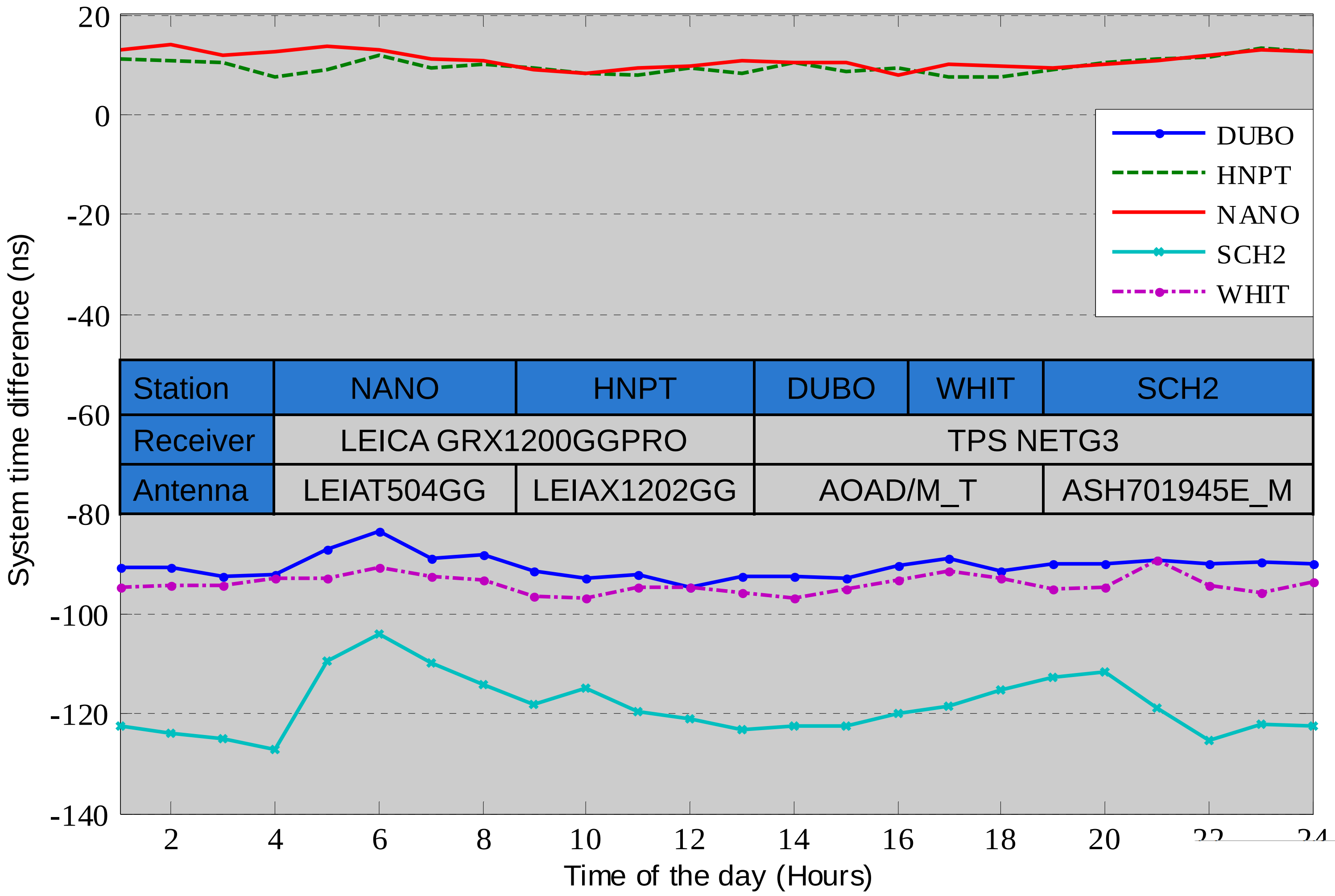
- Processing parameters:
  - L3 ionosphere-free observations;
  - 5 minutes sampling interval;
  - Elevation cut-off angle of 10^o;
  - Satellite cosine elevation-dependent weighting.

- The resulting coordinates were obtained in IGS05 frame and compared with the final IGS coordiantes.

Estimation of System Time Difference

M5

Hourly estimates of system time-difference



Station	NANO	HNPT	DUBO	WHIT	SCH2
Receiver	LEICA GRX1200GGPRO		TPS NETG3		
Antenna	LEIAT504GG	LEIAX1202GG	AOAD/M_T		ASH701945E_M

M5 . Figure shows the hourly estimation of TDGG at the selected IGS stations over 24 hours. As can be seen, the estimated hourly values of TDGG agree to within 10 ns, except for station SCH2. For stations with same receiver/antenna brand (Table 1), the system time difference values agree to within 5 ns. However, discrepancies of up to 130 ns in the values of TDGG occurred between stations with different receiver/antenna configuration, which reflect the contribution of hardware delay.

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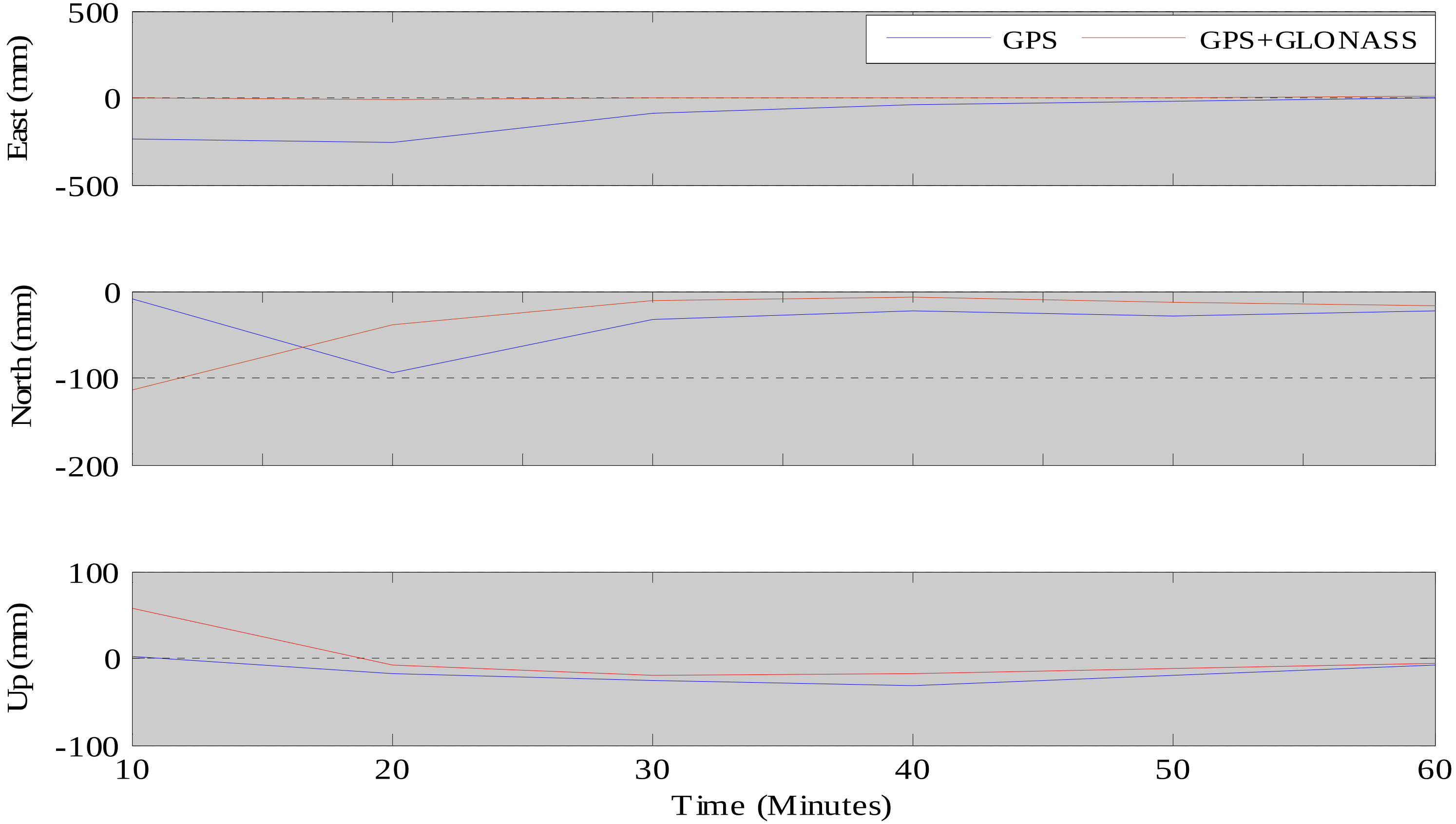
M7

PPP Results and Analysis

M8

Positioning solution convergence for station NANO, 60 minutes



M8 figure shows that positioning error converges to 5 cm within 20 minutes for the combined GPS/GLONASS solution, while it requires 50 minutes for the GPS-only solution to achieve the same accuracy level. the most significant improvemt was found to be in the East direction.
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M7 final solution accuracy results are presented for station NANO as an example. Similar results were obtained for the other stations.
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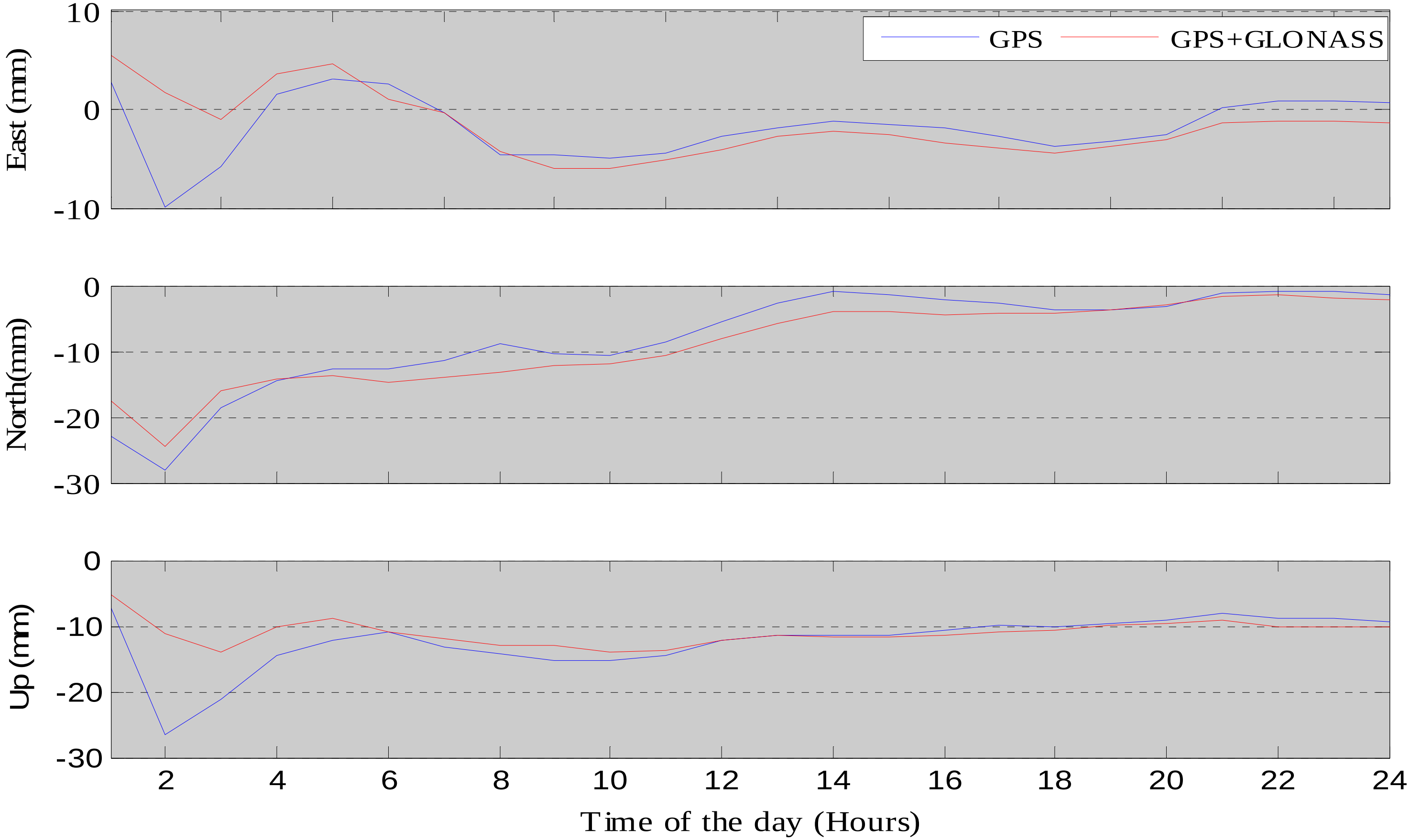
PPP Results and Analysis (Cont'd)

M9

Positioning solution convergence for station NANO, 24 Hours.



Dias nummer 13

M9 After one hour, the combined solution shows 30% improvement in positioning accuracy comparing with GPS-only solution. However, both of the two solutions become comparable after 6 hours.

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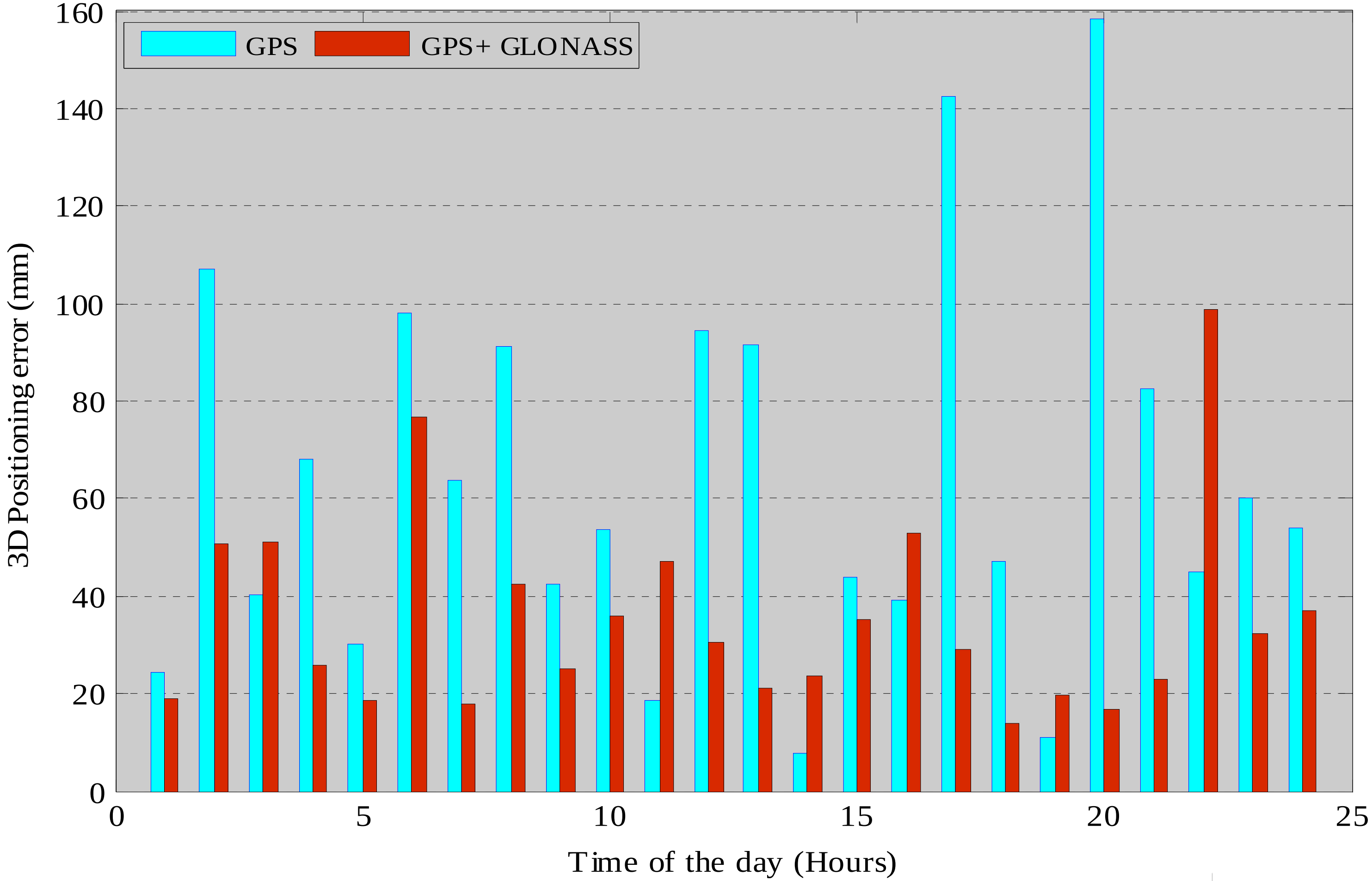
PPP Results and Analysis (Cont'd)

M10

PPP solution repeatability for station NANO with 1 hour observations



M10 Figure shows the hourly positioning error for both of GPS-only solution and combined GPS/GLONASS starting at different epochs of the day under consideration. As can be seen, the combined solution has better repeatability in 75% of cases.
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Conclusions

- This study investigated the performance of dual-frequency GPS/GLONASS PPP solution.

- It has been shown that the addition of GLONASS constellation improved the satellite availability and geometry by more than 30%. This allows for precise surveying in urban areas or when the satellite signal is partially obstructed.

Conclusions (Cont'd)

- The performance of the combined GPS/GLONASS PPP solution was found to be superior to that of GPS-only solution.
- A few centimetre-level accuracy can be achieved within 30 minutes with combined GPS/GLONASS PPP solution, while it requires about 3 hours with GPS-only solution.

Thank you!