Optimizing high-resolution troposphere estimates using PPP method and Benchmark data set

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Optimizing high-resolution troposphere estimates using PPP method and Benchmark data set

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COST ES1206/GNSS4SWEC 3rd Workshop

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Outline

- Our new approach for NRT estimates using Kalman filter + backward smoother

- Using GLONASS in the Benchmark campaign

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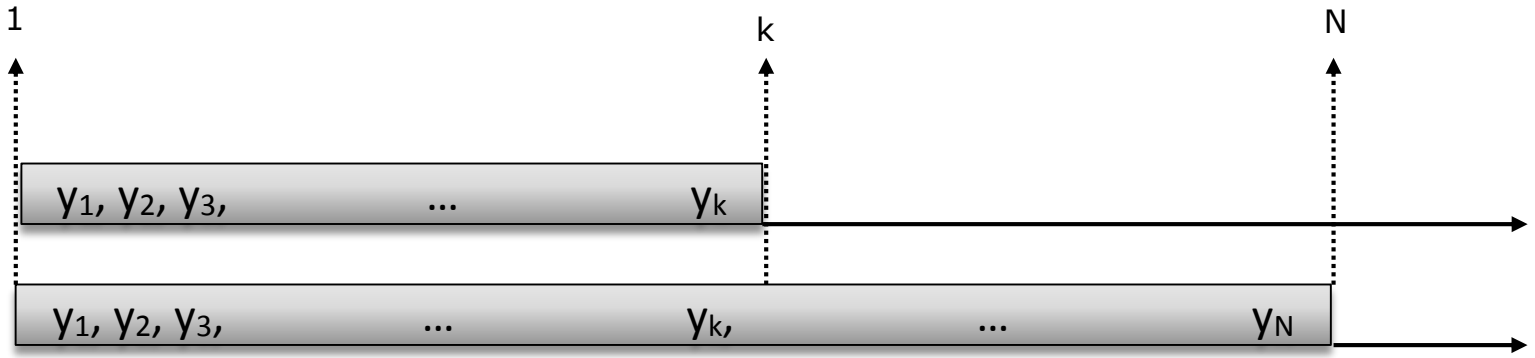
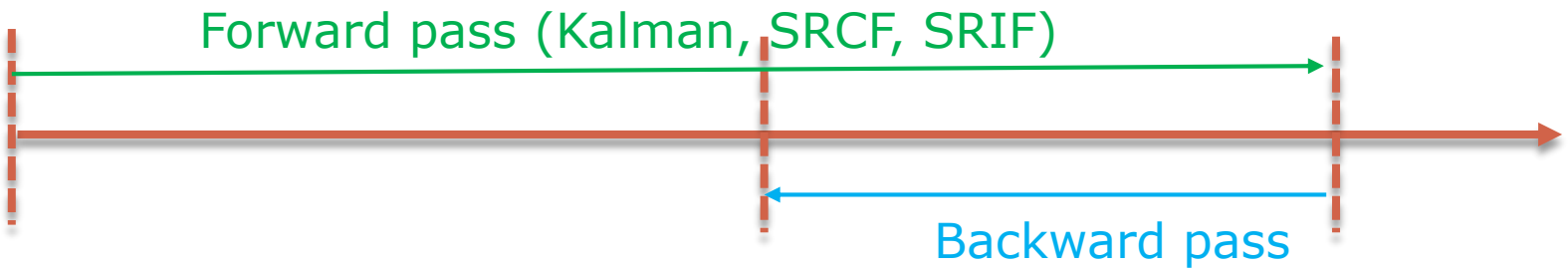
Principle of the forward-backward filter

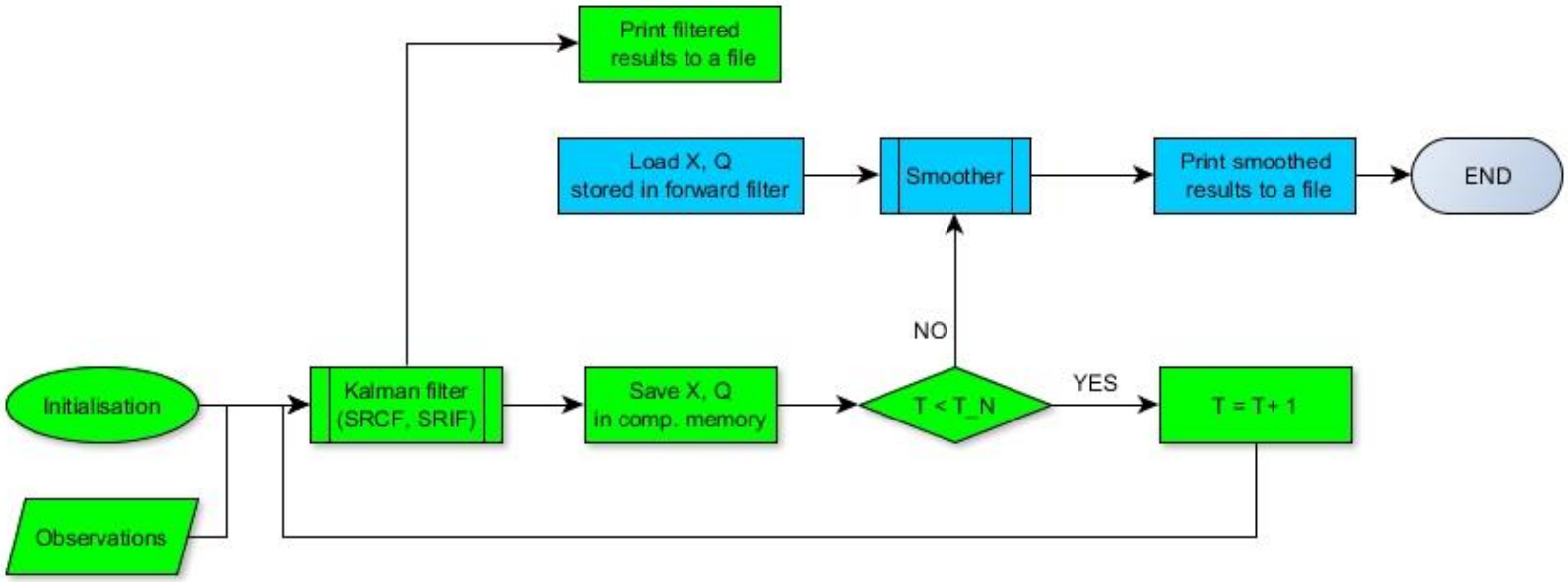
- Filtering: $X_{k|k} = E(X|y_1, y_2, y_3, \ldots, y_k)$
- Smoothing : $X_{k|N} = E(X|y_1, y_2, y_3, \ldots, y_k, \ldots, y_N)$





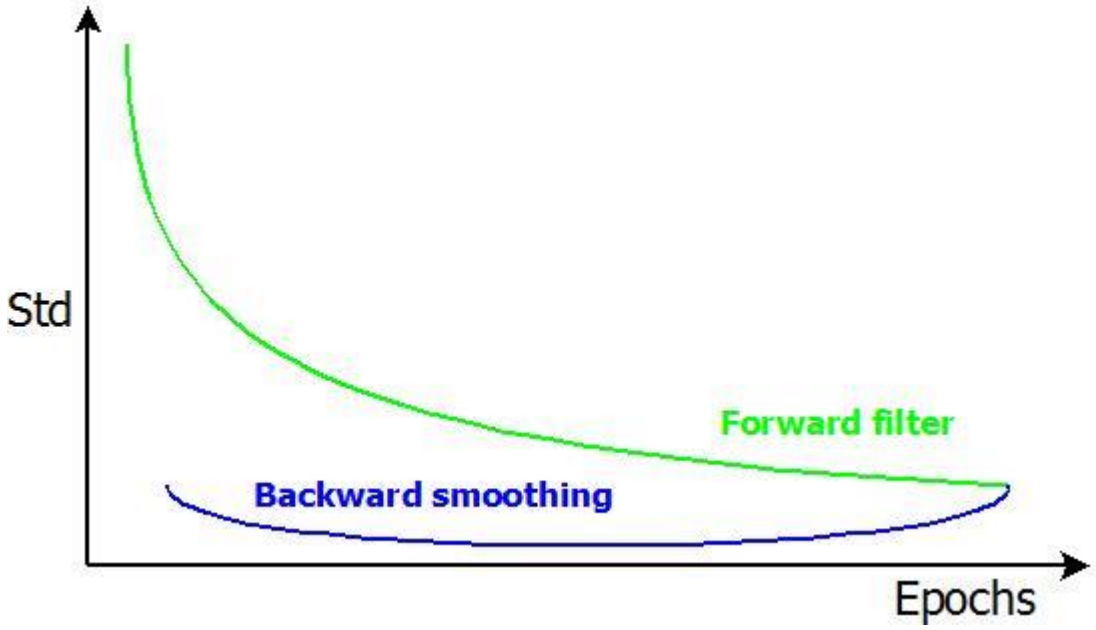
Principle of the forward-backward filter

Flow chart of the algorithm



Principle of the forward-backward filter

- Smoothing always improves precision w.r.t. filtering
- Almost the same precision in all epochs
- Observations from whole period contribute to all estimates - similar to LSQ, however with support for high-resolution estimates



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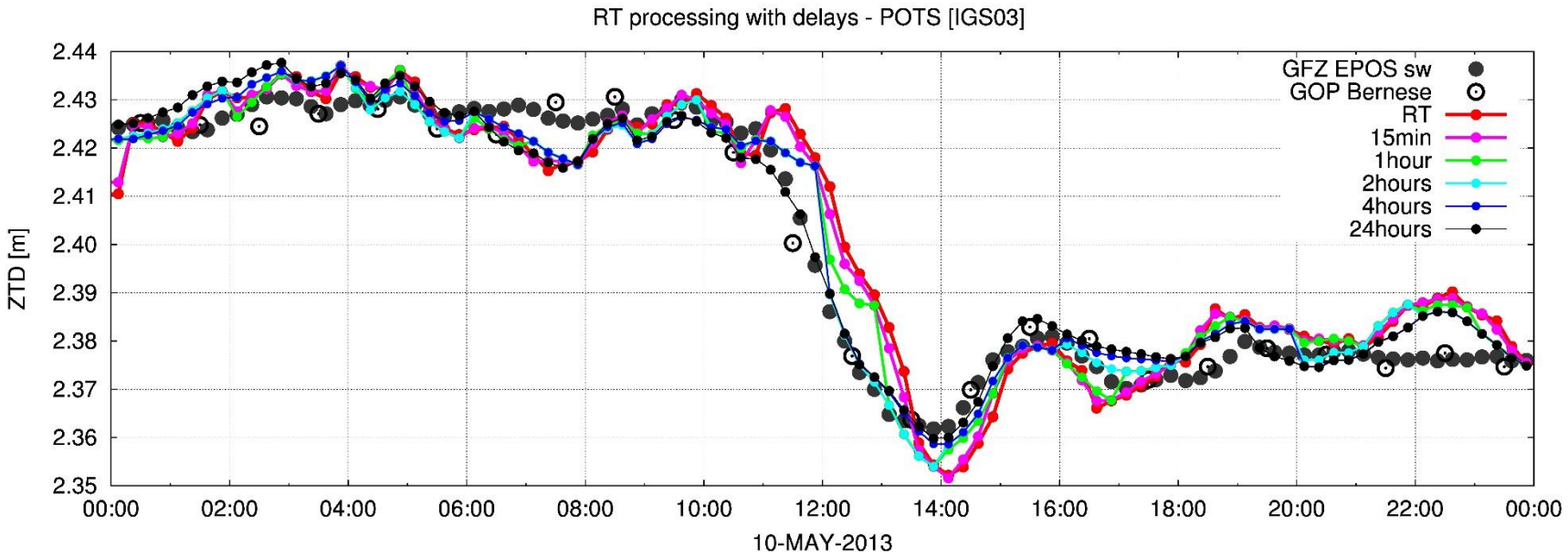
RT/NRT estimates
Kalman filter + backward smoother

- Reference ZTDs: GOP's Bernese (1h, network solution) and GFZ's (15min, PPP)
- Simulated RT ZTDs (IGS03 from IGS RTS): GOP's G-Nut/Tefnut software (30 s, PPP)
- NRT simulation (Kalman+smoother): different smoothing update: 15min, 1h, 2h, 4h, 24h



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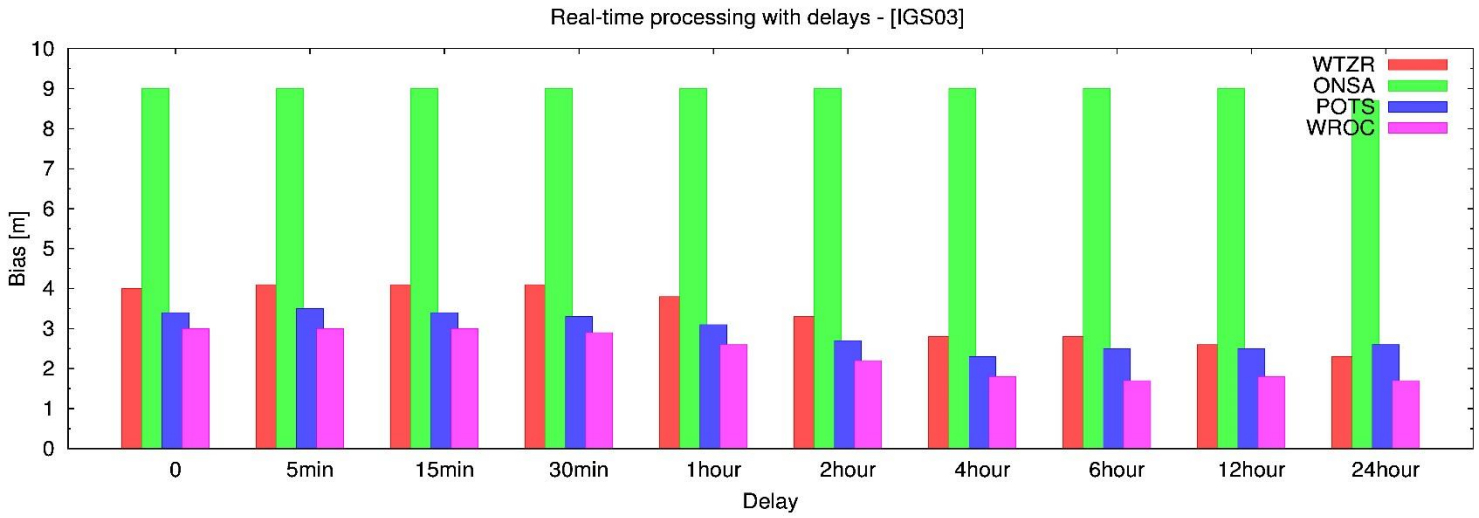
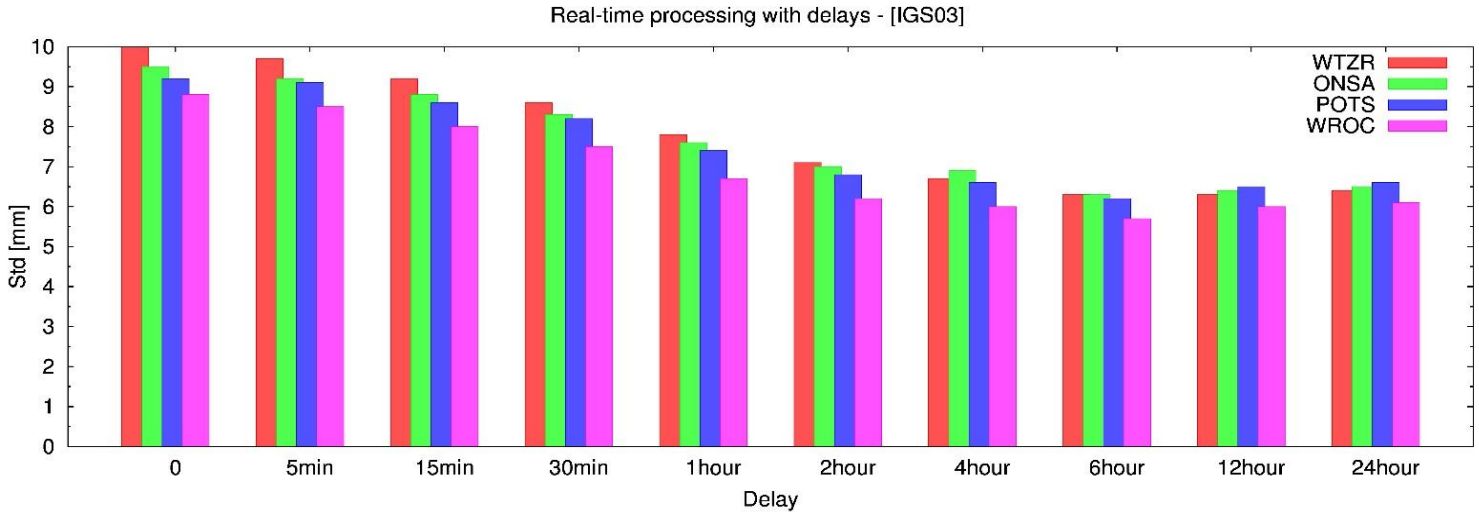
RT/NRT estimates
Kalman filter + backward smoother





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RT/NRT estimates
Kalman filter + backward smoother

- The precision of high-resolution ZTDs has been improved by smoother with delays up to 6 hours (up to 35% - from 10 mm to 6,5 mm)
- Backward filter optimizes an estimate if any parameter changes very rapidly – it uses not only previous observations but also subsequent
- Based only on matrix operation => very fast

  (e.g. forward: 21 s; backward 2 s)
- If real-time estimates are not necessary delayed results can be provided with better precision
- Smoothed parameters over the whole period have been estimated with the same precision

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Using GLONASS in the Benchmark campaign

- How to optimally set up GLO observation weighting
- Five solutions
  - Sol 1: GPS only: σ_{GPS}
  - Sol 2: GPS+GLO: $\sigma_{GLO} = 2\ \sigma_{GPS}$
  - Sol 3: GPS+GLO: $\sigma_{GLO} = 3\ \sigma_{GPS}$
  - Sol 4: GPS+GLO: $\sigma_{GLO} = 4\ \sigma_{GPS}$
  - Sol 5: GPS+GLO: $\sigma_{GLO} = 5\ \sigma_{GPS}$
- RT: PPP, forward filter, 5min, IGS03 RTS
- PP: PPP, forward filter, 5min, ESA final
- Reference ZTDs: GOP's Bernese (1h, network solution)
- First two hours of a day are not included in the evaluation => no convergence

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Using GLONASS in the Benchmark campaign

Sol 1
- GPS

Sol 2
- GPS + GLO
- $\sigma_{GLO} = 2\ \sigma_{GPS}$

Sol 3
- GPS + GLO
- $\sigma_{GLO} = 3\ \sigma_{GPS}$

Sol 4
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- $\sigma_{GLO} = 4\ \sigma_{GPS}$

Sol 5
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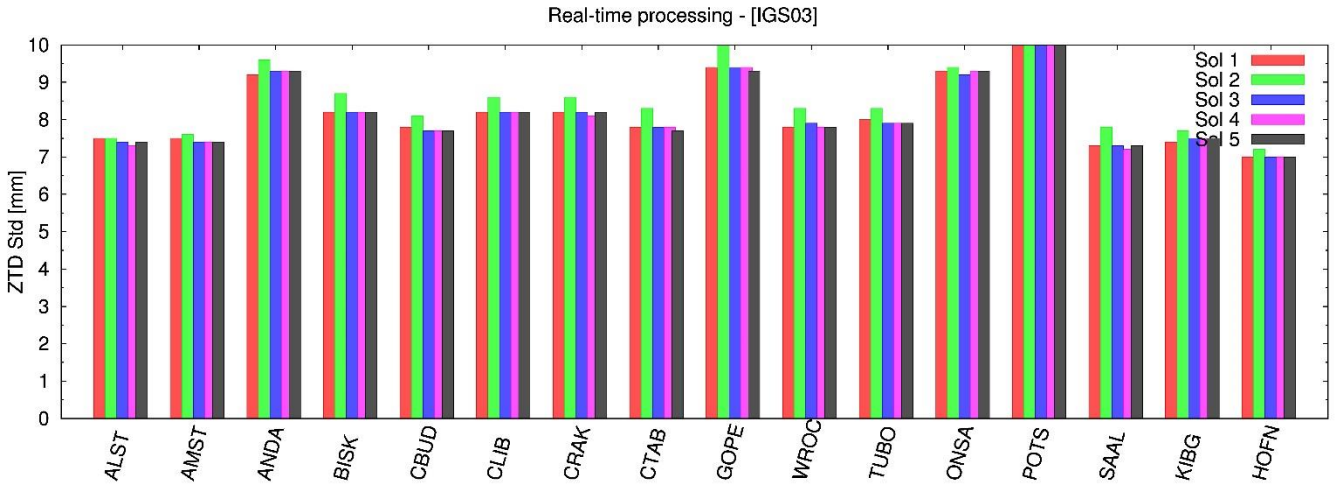
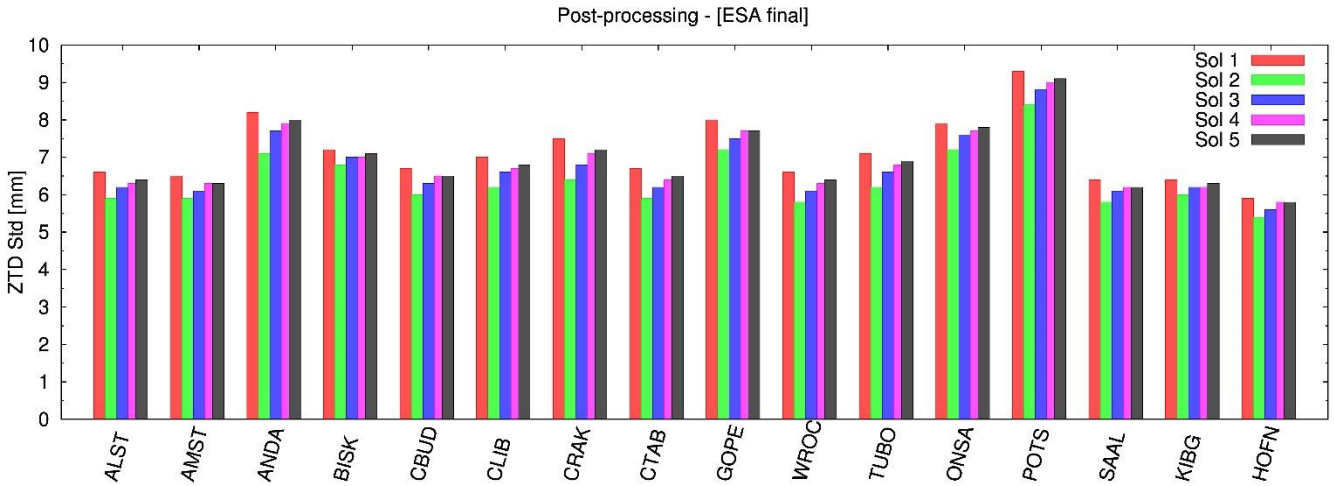
- $\sigma_{GLO} = 5\ \sigma_{GPS}$





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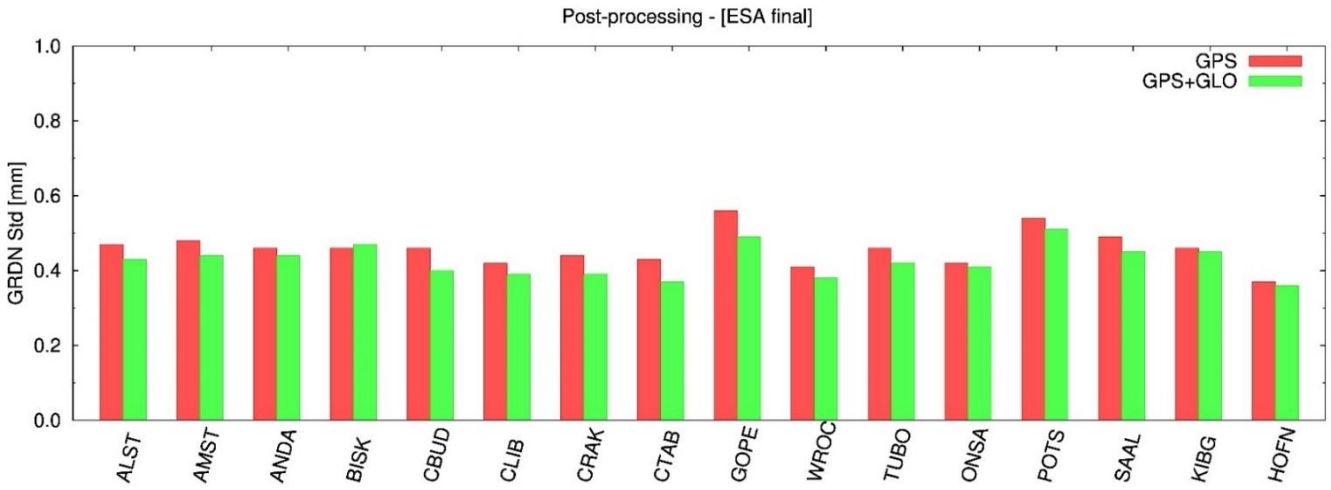
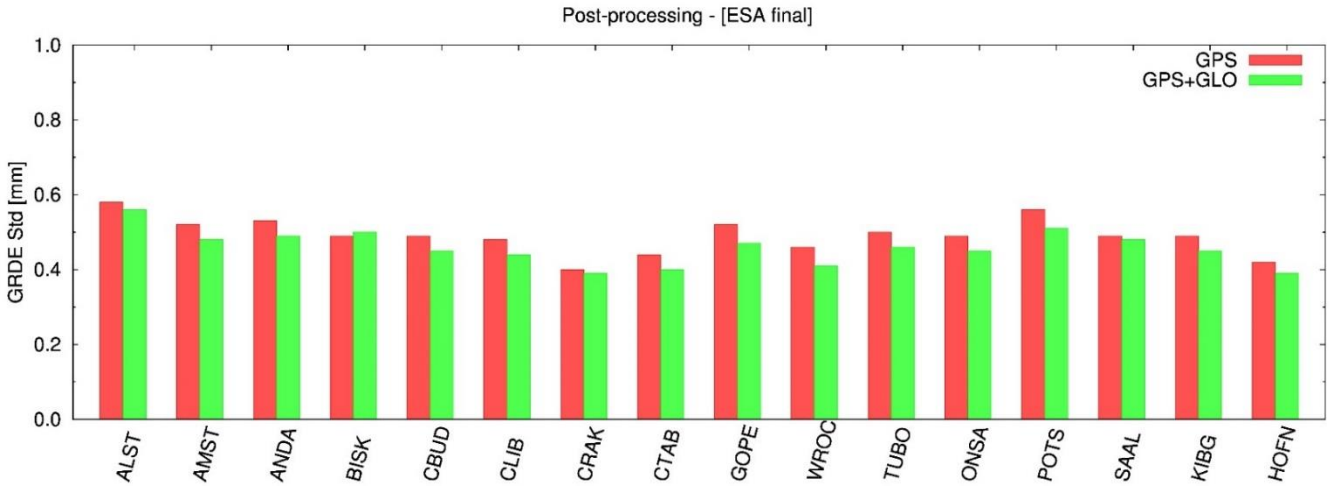
Impact of GLONASS on tropo gradients

GPS + GLO

- $\sigma_{GLO} = 2\ \sigma_{GPS}$
- Products: ESA final





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Impact of GLONASS on tropo gradients

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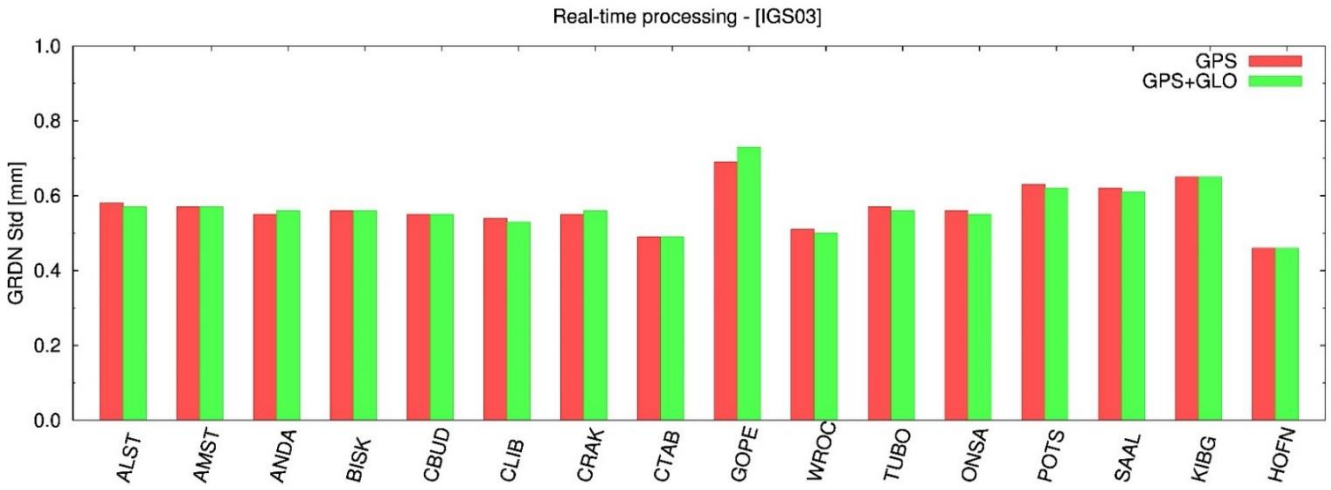
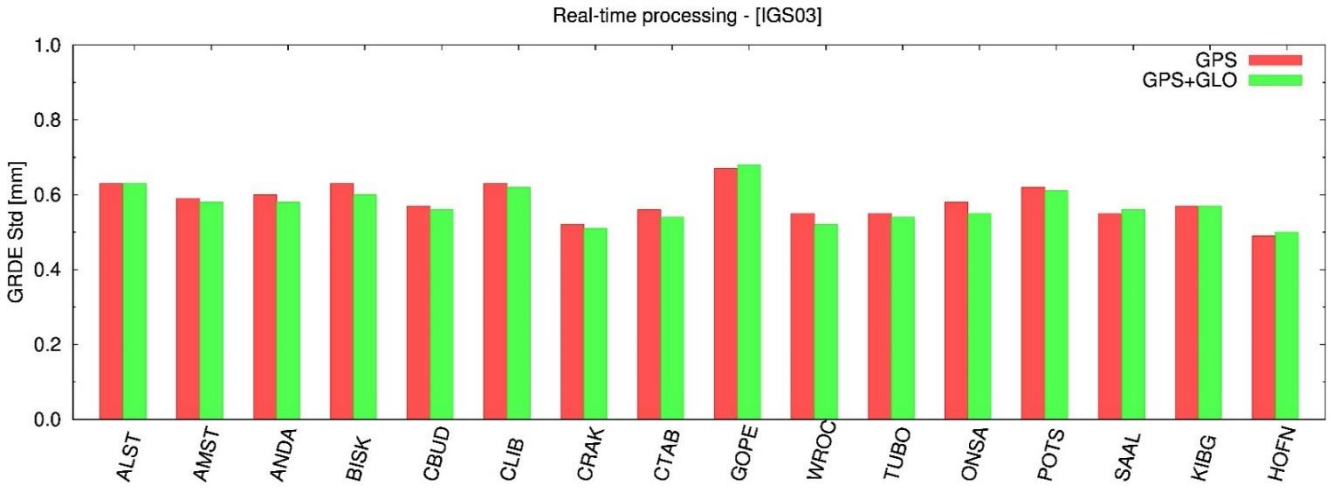
- Products: IGS03 RTS





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Conclusion

- ‘Ultra-fast’ troposphere estimates should be balanced for the delay & accuracy targeting the application
- PPP with bi-directional filter are powerful approach for estimation large dense network in high-resolution
- PPP provides full exploiting of multi-GNSS data
- Our approach for NRT can be immediately applied in RT-Demo campaign - traditional hourly estimates with LSQ can be replaced by bi-directional filter with one hour delay
- GLONASS improved troposphere estimates only when final products were used => low quality of RT products. (The same analysis should be done in 2016 for application in RT-Demo)

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Thank you for your attention

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Related publications:

Václavovic P, Douša J (2015), Backward smoothing for precise GNSS applications, Advances in Space Research, Volume 56, Issue 8, 15 October 2015, Pages 1627-1634

Douša J, Václavovic P (2014) Real-time zenith tropospheric delays in support of numerical weather prediction applications. Advances in Space Research (2014), Vol 53, No 9, pp 1347-1358

Douša J, Dick G, Kačmařík M, Brožková R, Zus F, Brenot H, Stoycheva A, Möller G, Kaplon J (2016), Benchmark campaign and case study episode in Central Europe for development and assessment of advanced GNSS tropospheric models and products, Atmos. Meas. Tech. Discuss., discussion paper, 2016

Ahmed F, Václavovic P, Teferle FN, Douša J, Bingley R, Laurichesse D (2015), Comparative analysis of real-time precise point poisitioning zenith total delay estimates, GPS solut, FirstOnline, pp. 1-13

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